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PREFACE.

THE papers and discussions presented at meetings of the Institute during the year 1914 will be published in three volumes. In order to preserve the chronological order of presentation, the present volume is devoted to the first meeting of the year, February, 1914.

As it was found impracticable to include in one volume all the papers presented at that meeting, the papers relating to iron and steel have been omitted and will be included in Vol. L, which is to contain the papers read at the meeting held in October, 1914, under the auspices of the Iron and Steel and other Committees, thus assembling in one volume all the material on iron and steel and related subjects which was presented at Institute meetings during the year.

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WILLIAM R. WALKER,
C. W. WHITLY,
H. A. J. WILKENS.

Proceedings of the One Hundred and Seventh Meeting of the American Institute of Mining Engineers

The 107th meeting of the Institute was held in New York City on Feb. 16 to 19, inclusive, 1914. Three hundred and twenty-three persons were registered and 68 papers were presented, for which 10 technical sessions were required.

The Committees having this meeting in charge were constituted as follows. To all of these persons the Institute extends its most sincere thanks for their generous efforts:

GENERAL COMMITTEE

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Thomas T. Read, *Secretary* | E. Maltby Shipp, *Treasurer*
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C. F. Chandler
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Levi Holbrook
J. H. Janeway
Thos. H. Leggett
Henry S. Munroe
Jos. W. Richards
E. Gybbon Spilsbury
Geo. C. Stone

RECEPTION

Tuesday, Feb. 17, 1914

Sidney J. Jennings, *Chairman*

R. M. Atwater, Jr.
Adolphe E. Borie
J. V. N. Dorr
E. O. Hovey
George F. Kunz
W. A. Pomeroy
H. A. Prosser
J. H. Van Mater
A. H. Wethey
Edw. L. Young

RECEPTION

Tuesday Evening, Feb. 17, 1914

E. O. Hovey, *Chairman*

P. A. Mosman, *Vice-Chairman*

Karl Eilers
James Gayley
Joseph A. Holmes
John H. Janeway, Jr.
Sidney J. Jennings
James F. Kemp
Charles Kirchhoff
Geo. F. Kunz
Albert R. Ledoux
Waldemar Lindgren
F. A. Lucas
H. F. Osborn
Rossiter W. Raymond
Joseph W. Richards
George C. Stone
Bradley Stoughton
Benjamin B. Thayer
Edward L. Young

RECEPTION

Wednesday, Feb. 18, 1914

Joseph Struthers, *Chairman*

William Campbell
L. W. Francis
John H. Hall
N. V. Hansell
E. O. Holter
Henry Marion Howe
J. E. Johnson, Jr.
Richard Moldenke
Leonard Waldo
H. V. Winchell

RECEPTION

Thursday, Feb. 19, 1914

Lawrence Addicks, *Chairman*

S. H. Ball
C. P. Berkey
J. V. N. Dorr
Ernst F. Eurich
W. R. Ingalls
J. S. Lane
Waldemar Lindgren
Carr B. Nell
Denis M. Riordan
Theodore Sternfeld

BUREAU OF REGISTRATION AND INFORMATION

Burr A. Robinson, *Chairman*

SOCIAL FEATURES.—Registration facilities were extended beginning on the afternoon of Monday, Feb. 16, and extending throughout the entire meeting.

On the evening of Feb. 16, at 8:30 o'clock, members and guests met in the Assembly Room on the fifth floor of the Engineering Societies, building, where greetings were extended on behalf of the Institute by President Charles F. Rand. This was followed by an illustrated address by Prof. James F. Kemp, and an address illustrated by lantern slides and moving pictures on the "Dangers of Field Photography" by a professional lecturer, then by an evening of social enjoyment in the rooms of the Institute on the ninth floor.

On Tuesday, Wednesday and Thursday noons, between the technical sessions, complimentary luncheons were served on the fifth floor.

On Tuesday evening, Feb. 17, the members and guests assembled in the American Museum of Natural History, where Howard W. DuBois gave a talk on "Hydraulic Mining in British Columbia," illustrated by colored lantern slides. This was followed by an illustrated lecture by Dr. E. O. Hovey on the "Copper Queen Mine," following which an informal collation was served and an opportunity afforded for the inspection of the model of the Copper Queen Mine and the working model of one of the stopes, which have been presented to the Museum by Dr. James Douglas.

On Wednesday evening, Feb. 18, a subscription dinner was held at the Waldorf-Astoria. This dinner was attended by 200 members and guests, and was preceded by a reception to the newly-elected President, the retiring President, and their wives. W. L. Saunders acted as toastmaster, and speeches were made by Past President Charles F. Rand, President Benjamin B. Thayer, Dr. R. W. Raymond, Ex-Senator W. W. Clark, Senator T. J. Walsh, Thomas B. Stearns, and D. M. Riordan.

On Thursday afternoon, Feb. 19, a *Thé Dansant* was given for the ladies at the Castle House, and proved a very enjoyable feature.

BUSINESS AND TECHNICAL SESSIONS.—The annual business meeting was held at 10 a.m., Tuesday, Feb. 17, at which the following officers and directors were elected:

Director and President.

BENJAMIN B. THAYER.

Directors and Vice-Presidents.

HERBERT C. HOOVER,
WILLIAM L. SAUNDERS.

Directors.

REGINALD W. BROCK, ALBERT R. LEDOUX,
D. C. JACKLING, CHARLES W. MERRILL,
HENRY L. SMYTH.

The following papers were then read by their authors or authors' representatives:

H. A. Guess, Mining and Mining Methods in the Southeast Missouri Disseminated-Lead District.

James Johnston, The Mill and Metallurgical Practice of the Nipissing Mining Co., Ltd., Cobalt, Ont., Canada. (Discussed by E. G. Spilsbury, T. T. Read, George A. Packard, and Reginald E. Hore.)

On Tuesday afternoon, the following papers were read by their authors or authors' representatives:

H. H. Clark, Safeguarding the Use of Electricity in Mines. (Discussed by George S. Rice and B. F. Tillson.)

H. W. Rogers, The Application of Electric Motors to Shovels. (Discussed by William Kelly, E. G. Spilsbury, T. T. Read, and F. H. Armstrong.)

* Sanford B. Belden, Recent Developments in the Design of Jeffrey Locomotives and Coal-Cutting Machines. (Discussed by E. W. Parker and R. R. Dunlop.)

Charles Legrand, Electric Traction in Mines.

C. M. Means, The Safety of Underground Electrical Installations.

S. LeFevre, Application of Electricity to Mines and Mills of Witherbee, Sherman & Co., Inc., Mineville, N. Y.

William Kelly and F. H. Armstrong, Use of Electricity at the Penn and Republic Iron Mines, Michigan. (Discussed by K. A. Pauly, B. F. Tillson, and J. E. Johnson, Jr.)

W. L. Saunders, Drilling Performances at the Kensico Dam, Catskill Aqueduct System, New York.

Arthur F. Taggart, The Work of Crushing.

Francis Donaldson, The Injection of Cement Grout into Water-Bearing Fissures. (Discussed by Frank Firmstone, G. S. Wright, and A. C. Lane.)

The following paper was read by title:

*S. B. King, Recent Developments in Electric Coal-Mining Machines.

On Wednesday morning, Feb. 18, simultaneous sessions were held in different rooms under the auspices of different technical committees, as follows:

Iron and Steel Committee

The following papers were read by their authors or authors' representatives:

† H. M. Howe and A. G. Levy, Notes on the Plastic Deformation of Steel During Overstrain. (Discussed by H. C. H. Carpenter, H. D. Hibbard, W. R. Webster, R. H. Sweetser, and C. P. Linville.)

* Not included in this volume. † Held for publication in vol. 1.

†Albert Sauveur, Notes on Some Heating and Cooling Curves of Professor Carpenter's Electrolytic Iron. (Discussed by H. C. H. Carpenter and H. M. Howe.)

†J. E. Johnson, Jr., The Influence on the Quality of Cast Iron Exerted by Oxygen, Nitrogen, and Some Other Elements. (Discussed by Richard Moldenke, H. D. Hibbard, C. H. Strand, W. R. Webster, J. H. Hall, A. Sauveur, Bradley Stoughton, William Campbell, and R. H. Sweetser.)

†C. D. Young, O. D. A. Pease, and C. H. Strand, The Heat Treatment of Steel Castings. (Discussed by E. F. Cone and J. H. Hall.)

†W. S. Potter, Manganese Steel, with Especial Reference to the Relation of Physical Properties to Microstructure and Critical Ranges.

†Prof. B. Hopkinson and Sir Robert Hadfield, Research with Regard to the Non-Magnetic and Magnetic Conditions of Manganese Steel. (Discussed by W. S. Potter and H. M. Howe.)

The following papers were read by title:

†C. M. Weld, Notes on an Iron-Ore Deposit near Hong-Kong, China.

†Sir Robert Hadfield, The Progress of the Metallurgy of Iron and Steel.

Committee on Mining Law

The following papers were read by their authors or authors' representatives:

R. W. Raymond, Comparison of Mining Conditions To-day with those of 1872, in their Relation to Federal Mineral-Land Laws.

Charles H. Shamel, Should the Apex Law be Now Repealed? (Discussed by R. W. Raymond and Senator T. J. Walsh.)

Charles W. Goodale, The Apex Law in the Drumlummon Controversy. (Discussed by R. W. Raymond and Senator T. J. Walsh.)

George Otis Smith, The Classification of Public Lands.

George Otis Smith, The Disposition of Natural Resources.

Albert Burch, The Initiation of Title to Mineral Lands. (Discussed by G. A. Packard and R. W. Raymond.)

F. L. Sizer, Good Ideas in the Mining Laws of British Columbia and Mexico. (Discussed by S. J. Jennings and W. L. Cumings.)

On the same afternoon simultaneous sessions were held in different rooms under the auspices of the different technical committees, as follows:

Iron and Steel Committee

The following papers were read by their authors or authors' representatives:

†S. G. Valentine, Notes on Blast-Furnace Operation with a Turbo Blower. (Discussed by J. E. Johnson, Jr., J. W. Richards, K. Nibecker, and Leonard Waldo.)

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† Held for publication in vol. l.

†A. N. Diehl, Data Pertaining to Gas Cleaning at the Duquesne Blast Furnaces. (Discussed by A. E. MacCoun, F. L. Grammer, J. W. Richards.)

†Heinrich J. Freyn, Notes on the Utilization of Coke-Oven and Blast-Furnace Gas for Power Purposes. (Discussed by Richard Lamb, A. E. MacCoun, J. E. Johnson, Jr., and Richard Moldenke.)

†C. B. Murray, The Need of Uniform Methods of Sampling Lake Superior Iron Ore. (Discussed by William Kelly, and R. H. Sweetser.)

The following papers were read by title:

†R. W. Hunt, American Steel-Rail Situation.

†Sir Robert Hadfield, Manganese-Steel Rails. (Discussed by W. S. Potter and J. W. Richards.)

†Robert M. Keeney, Pig Steel from Ore in the Electric Furnace.

†Charles K. Leith, Notes on Conservation of Lake Superior Iron Ores.

†Sir Robert Hadfield, Sound Ingots.

Committee on Mining Law

The following papers were read by their authors or authors' representatives:

Horace V. Winchell, Why the Mining Laws Should be Revised. (Discussed by R. W. Raymond, Hennen Jennings, Sidney J. Jennings, and G. O. Smith.)

Frederick F. Sharpless, The Segregation and Classification of the Natural Resources of the Public Domain.

Will L. Clark, Location of Mining Claims upon Indian Reservations.

E. B. Kirby, Mining Law Revision—How to Obtain It. (Discussed by H. V. Winchell, J. B. Tyrrell, R. W. Raymond, Senator T. J. Walsh, George A. Packard, D. M. Riordan, and Hennen Jennings.)

The following papers were read by title:

C. L. Colburn, Uniform Mining Legislation in all the States Based on Federal Act.

George W. Riter, Character of Title that Should be Granted by Government.

At 4:30 P.M. Samuel A. Taylor gave an illustrated address on The Mining of Bituminous Coal.

On Thursday morning, Feb. 19, simultaneous sessions were held in different rooms, under the auspices of the different technical committees, as follows:

Committee on Mining Geology

The following questions were discussed:

1. To what depth below the surface do the standing ground-waters

† Held for publication in vol. 1.

extend? (Opened with a paper by Alfred C. Lane and discussed by J. F. Kemp, F. L. Ransome, T. T. Read, L. C. Graton, E. C. Bastin, and J. D. Irving.)

2. To what extent is chalcocite a primary, and to what extent a secondary, mineral in ore deposits? (Discussed by L. C. Graton, J. D. Irving, T. T. Read, F. L. Ransome, and Waldemar Lindgren.)
3. To what extent are the contact zones, often called garnet zones, produced by intrusive rocks from limestone walls, due to recrystallization of matter original with the limestones; and to what extent are they and their associated ores due to contributions from intrusive rocks? (Opened with papers by Waldemar Lindgren and C. K. Leith and discussed by A. C. Lane, J. F. Kemp, and J. D. Irving.)

Committee on Petroleum and Gas

The following papers were read by their authors or authors' representatives:

W. N. Best, Scientific Installations for the Economical Burning of Liquid Fuel of Any Specific Gravity. (Discussed by E. H. Hamilton, H. O. Hofman, K. Nibecker, Leonard Waldo, and E. G. Spilsbury.)

George Otis Smith, An Oil-Land Law. (Discussed by Eugene Coste, Hennen Jennings, and Walter O. Snelling.)

C. W. Washburne, Chlorides in Oil-Field Waters. (Discussed by Eugene Coste.)

Hans von Höfer, The Origin of Petroleum. (Discussed by A. F. Lucas, Eugene Coste, I. N. Knapp, W. C. Phalen, and C. W. Washburne.)

The following papers were read by title:

H. A. Wheeler, The Illinois Oil Fields.

L. W. Page, The Use of Petroleum in Dust Prevention and Road Preservation.

C. D. Keen, The Killing of the Burning Gas Well in the Caddo Oil Field, Louisiana.

On Thursday afternoon simultaneous sessions were held in different rooms, under the auspices of the different technical committees, as follows:

Committee on Petroleum and Gas

The following papers were read by their authors or authors' representatives:

Eugene Coste, Rock-Disturbances Theory of Petroleum Emanations *vs.* the Anticlinal or Structural Theory of Petroleum Accumulations.

S. S. Wyer, Is it Feasible to Make Common Carriers of Natural Gas Transmission Lines?

Max W. Ball, The Placer Law as Applied to Petroleum.

I. N. Knapp, Cementing Oil and Gas Wells.

The following papers were read by title:

Franklyn W. Oatman, Water Intrusion and Methods of Prevention in California Oil Fields.

E. T. Dumble, The Age and Manner of Formation of Petroleum Deposits.

Ralph Arnold and V. R. Garfias, Geology and Technology of the California Oil Fields.

Alexander Adiassevich, The Russian Oil Fields.

John R. Edwards, The Maritime Features of the "Crude Petroleum" Problem.

William B. Phillips, Fuel Oil in the Southwest.

Papers on Miscellaneous Subjects

The following papers were read by their authors or authors' representatives:

Carle R. Hayward, The Equilibrium Diagram of the System Cu_2S–Ni_3S_2. (Discussed by H. O. Hofman.)

Robert Linton, Cyanidation of Silver Sulphide at Ocampo, Mexico.

The following papers were read by title:

H. W. Turner, Nickel Deposits in the Urals.

Alexander Bowie, The Burning of Coal Beds in Place.

*Herbert Haas, A Proposed New Converter, and the Application of the Bessemerizing Process to the Smelting of Ores.

A. C. Boyle, Jr., The Geology and Ore Deposits of the Bully Hill Mining District, California. (Discussed by E. G. Spilsbury, G. A. Packard, and L. C. Graton.)

At 4 P.M. I. N. Knapp delivered an illustrated address on Oil and Gas Sands.

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* Not included in this volume.

PAPERS

The Mill and Metallurgical Practice of the Nipissing Mining Co., Ltd., Cobalt, Ont., Canada

BY JAMES JOHNSTON, COBALT, ONT., CANADA

(New York Meeting, February, 1914)

Synopsis.—A description of the working of the mills of this company and the metallurgical practice in vogue, by which a remarkably complex silver ore, averaging 54 oz. of silver per ton (run-of-mine ore), is treated to give a 95.66 per cent. extraction.

The main features of the processes are:

The cyanide amalgamation of the high-grade ore.

The cyanide treatment of the low-grade ore, after extremely fine grinding and close classification, in a caustic soda solution.

The use of a wet desulphurizing process to break up refractory silver minerals.

The substitution of aluminum dust for zinc dust as a precipitant.

The recovery and shipment of over 13,000,000 oz. of silver in bullion at 997 to 999 fine since this metallurgy was inaugurated, about 2.5 years ago.

On the completion and successful operation of the mill to treat their high-grade ore,[1] the Nipissing Mining Co., under the general management of R. B. Watson, started a series of investigations of the possible treatment of the low-grade ore by the cyanide process, so that they would be in a position to market only silver bullion. These tests were run in July, 1911, on a large scale, by G. H. Clevenger, on an average mixture of Nipissing ore. The results obtained by a partial amalgamation followed by cyanide treatment gave an extraction varying from 90 to 93 per cent. and were sufficiently encouraging to warrant Charles Butters, the company's Consulting Metallurgist, in recommending that the new low-grade ore mill under contemplation should be a cyanide mill, instead of a concentrator. The cost of such a mill, capable of treating 200 tons per day, to obtain a 90 per cent. extraction at a working cost of $3 per ton of ore treated, was estimated at $250,000.

In coming to a decision as to which type of mill should be erected, the concentrator, with the subsequent shipping of concentrates to a smeltery,

[1] R. B. Watson: Nipissing High-grade Ore Mill, Cobalt, *Engineering and Mining Journal*, vol. xciv, No. 23, p. 1077 (Dec. 7, 1912). See Fig. 4 of this paper.

was compared with what could be done in a cyanide mill shipping silver bullion 999 fine.

Comparison of Mills Treating 200 *Tons Per Day*

Commercial assay of ore	30.99 oz.
Correction on pulp	1.10 oz.
Corrected assay	32.09 oz.

Concentration Mill to give an 80 per cent. extraction. Approximate cost, $160,000			Cyanide Mill to give a 90 per cent. extraction. Approximate cost, $250,000		
80 per cent. × 32.09 oz. = 25.67 oz. at 52 c. =		$13.35	90 per cent. × 32.09 oz. = 28.88 at 52 c. plus $\frac{3}{10}$ c. increase price in marketing =		$15.16
Working costs =	$1.25		Working costs =	$3.00	
Marketing concentrates, 10 per cent.	1.33		Express on bullion, $3.50 per cwt. = 23 c. per oz. on 28.88 oz. =	0.07	3 07
Difference between corrected and commercial assay on concentrates = 2 per cent.	0.27	2.85			
Profit per ton		$10.50	Profit per ton		$12.09

Profit per ton from cyanide mill	$12.09
Profit per ton from concentration mill	10.50
Profit in favor of cyanide mill, per ton of ore treated	$1.59

Thus it will be seen that a cyanide mill after having treated 56,600 tons (283 days' run) would have reimbursed the company for the extra $90,000 required for its construction, providing it were possible to obtain these results.

The actual results which are now being obtained in the cyanide mill are as follows:

Cost of construction	$254,839.52
Extraction on a 26-oz. ore, per cent.	92 to 93
Working costs, per ton, less than	$3.00
Tonnage treated per day	244

The above figures prove conclusively that the results obtained in the preliminary experiments have been more than borne out in actual practice, thus fully justifying the adoption of this type of treatment.

The cyanide mill has an additional advantage over the concentrator, in that it is able to get an extraction of over 90 per cent. on the arsenic-antimony-silver combinations and on decomposed silver minerals found in some veins, on which concentrators can make only a poor saving.

While the construction of the mill was in progress further experimental work was being proceeded with in the expectation of simplifying and bettering the process as it was then known, and to more fully appreciate and overcome the difficulties that others had experienced in their

unsuccessful attempts to make the Cobalt ores amenable to an all-cyanide treatment. Some of these results have been ably recorded by J. J.

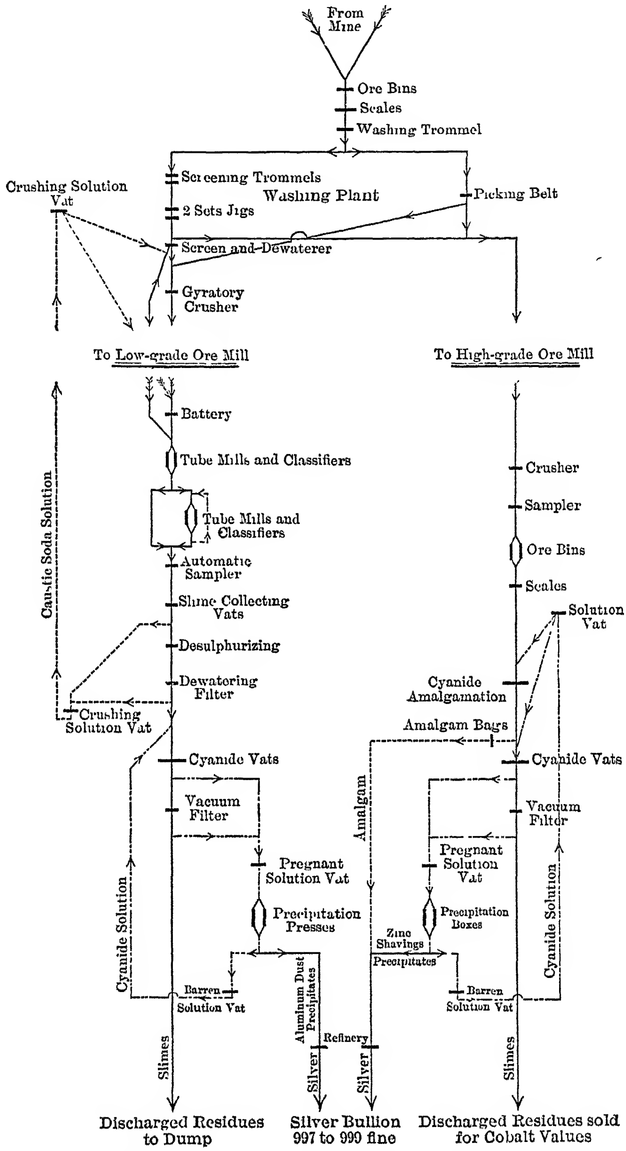

FIG. 1.—FLOW SHEET OF NIPISSING MINING CO.'S MILLS.

Denny.[2] In regard to the difficulties experienced elsewhere by the fouling of the cyanide solutions where zinc dust was used as a means of pre-

[2] *Mining and Scientific Press,* vol. cvii, No. 13, p. 484 (Sept. 27, 1913).

cipitation, E. M. Hamilton[3] fully records the conclusions that led up to the adoption of aluminum dust in this mill.

A mill with a proposed capacity of 200 tons per day was designed by Mr. Butters and myself, and provision was made in the plan so that any

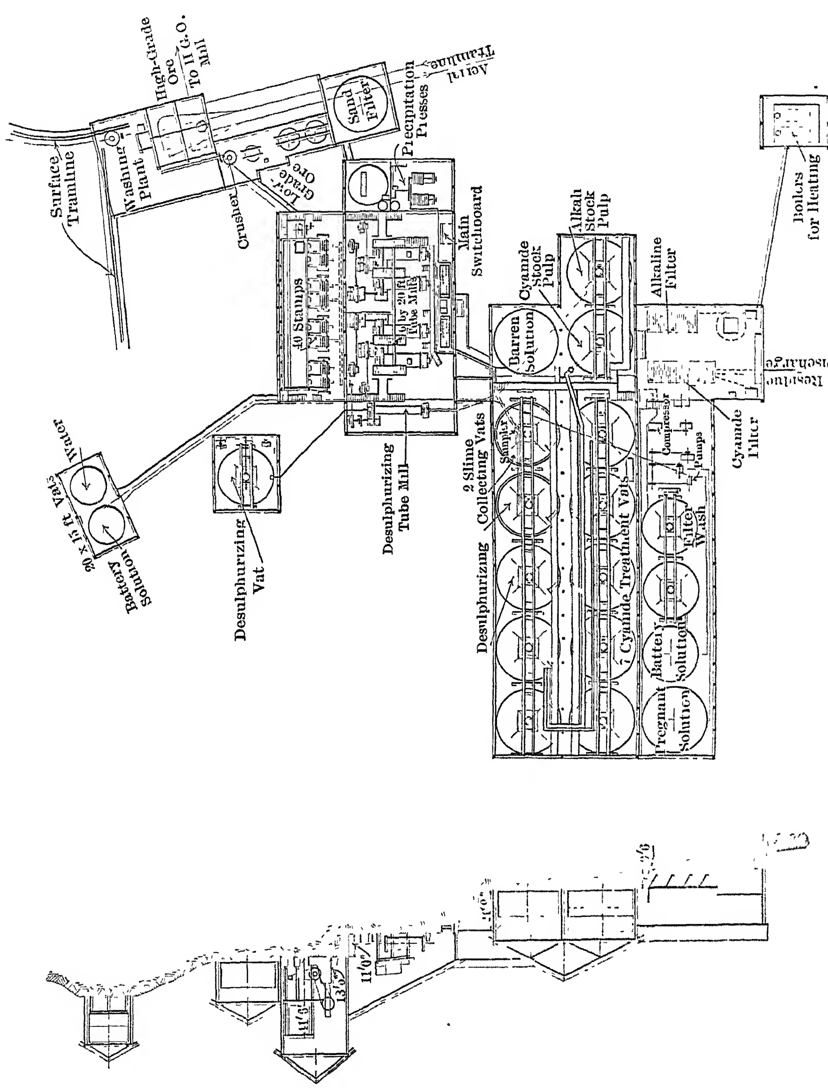

Fig. 2.—Plan and Section of the Low-Grade Ore Mill of the Nipissing Mining Co., Ltd

change could be made during construction should the results on the further experimental work which Mr. Butters had suggested indicate that everything could be treated by an all-cyanide process. The experience

[3] *Engineering and Mining Journal*, vol. xcv, No. 19, p. 935 (May 10, 1913).

gained from these tests resulted in modifications of the plans and flow sheet before the erection was completed, so as to introduce into the treatment the aluminum dust precipitation and the desulphurizing process.

Briefly, the mill practice is as follows:

Crushing the ore to 3 in. in gyratory crushers before sending it to washing plant.

Hand picking and jigging of the high-grade ore in the washing plant, which is then sent to high-grade ore mill.

Discards from washing plant, known as low-grade ore, crushed to 1.5-in. mesh and sent to battery.

Crushing in battery and tube mills in a caustic soda solution to all slimes.

Collecting slimes and desulphurizing in tube mill and vat.

Dewatering slimes and transferring to vats for cyanide treatment.

Filtering slimes and discharging to waste dump.

Cyanide solution from slime treatment vats and filters going to aluminum dust precipitation.

Aluminum dust precipitate taken to refinery, melted, and refined to silver bullion at 997 to 999 fine.

The flow sheet of the process is shown in Fig. 1, and the low-grade ore mill is shown in plan and section in Fig. 2.

The mill site is on practically the highest point of Nipissing hill and is so located that easy tram-line communication can be made between any point on the company's property and the mill. Ample dump capacity for residues is provided below the mill.

Excavations

Excavation was started in November, 1911, and the following data give the cost for soil and rock work. The figures given are fair averages.

Soil Work on Tank-Floor Level, 2,404 *Cu. yd.*

Labor	$1,369.00
Sundry supplies	59.76
Teaming	6.03
Blacksmith's shop	17.60
Total	$1,452.39 = $0.604 per cu. yd.

Rock Work on Same Floor, 3,144 *Cu. yd.*

Labor	$5,539.00
Sundry supplies	123.52
Explosives	279.41
Blacksmith's shop	102.75
Air: Drills	1,196.32
Hauling rock to dump	1,503.68
Lumber	25.50
Total	$8,770.18 = $2.79 per cu. yd.

Soil work on other grades cost $0.41 per cubic yard, and rock work $1.48 per cubic yard.

Foundations

The walls for buildings and machinery foundations are of concrete. The crushing and mixing plant was located on a level above the uppermost floor and from there the concrete was transferred by chutes and cars into the various foundation forms, the necessary machinery being driven by compressed air. A mixture of 1 of cement, 3 of sand, and 5 of stone, together with the addition of all the large stone the concrete could take as it lay in place in the forms, was used generally throughout the foundations, with the exception of battery, tube mill, and other machinery foundations which are subject to much vibration; for these, the upper 1 or 2 ft. of the foundation was strengthened by the addition of more cement. The following are representative costs:

Battery Foundation and Walls for the Building and Ore Bins

Battery block	=846 cu. yd. concrete
Building and walls	=349 cu. yd. concrete
Total.........	1,195 cu. yd., used 945 bbl. cement

Labor..................................	$2,669.48
Supplies...............................	3,735.33
Lumber.................................	246.57
Carpenter shop labor....................	790.86
Machine shop labor......................	87.78
Teaming................................	139.34
Fuel...................................	12.85
Air for operating machinery.............	400.00
Total..............................	$8,082.21 = $6.76 per cu. yd.

Retaining Walls and Sundry Small Walls and Foundations on Tank-Floor Level

434 cu. yd., used 485 bbl. cement

Labor..................................	$1,645.57
Supplies...............................	2,152.52
Lumber.................................	337.76
Carpenter shop labor....................	1,180.05
Machine shop labor......................	26.09
Teaming................................	26.33
Fuel...................................	12.85
Air for operating machinery.............	300.00
Total..............................	$5,681.17 = $13.09 per cu. yd.

Cement was shipped to the mill in bags, four to a barrel, the total consumption being 3,355 bbl. at an average cost of $2.06 per barrel.

The various forms for concrete foundations, etc., around the mill made use of 26,339 ft. B.M. of 1-in. boarding and 20,771 ft. B.M. of

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FIG. 3.—LOW-GRADE ORE MILL OF NIPISSING MINING CO., LTD.

other sizes of lumber, part of which when taken down was made use of for other purposes.

The Mill Building

The mill building is constructed of wood framing covered with 1-in. boarding, building paper, and corrugated iron, so as to make a warm

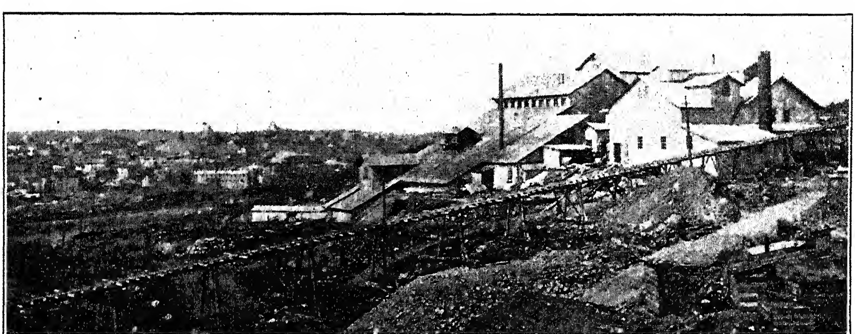

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FIG. 4.—HIGH-GRADE ORE MILL OF NIPISSING MINING CO., LTD.

building for winter service. There was used in its construction 398,601 ft. B.M. of lumber, of which 148,250 ft. B.M. was 1-in. boarding. The

total lumber used in the whole mill was 1,199,206 ft. B.M., at a value of $23,731.33. Fig. 3 is a photographic view of the low-grade ore mill. The high-grade ore mill is shown in Fig. 4.

The following statements cover the complete cost of the construction of the mill. These accounts were closed about three months after the mill went into operation, so that all the adjustments made necessary after the starting of a mill in which some new departures in metallurgy are being exploited are included in these total costs.

The original estimated cost of this section of the mill as enumerated in the following list of departments was made in October, 1911, and totaled $250,000.

Cost of Construction of the Low-Grade Ore Mill (Crushing and Cyanide Section)

Departments	Cost to Jan. 31, 1913
Store and office buildings	$725.65
Proportion office and supervision during construction	6,652.97
Excavations	29,728.30
Foundations	20,159.39
Buildings over mill	24.618.99
Battery equipment	24.241.42
Battery equipment, proportion electrical equipment	5,267.38
Tube mills and classifiers	23,223.80
Tube mills and classifiers, proportion electrical equipment	12,091.02
Slime treatment and storages	31,519.84
Slime treatment and storages, proportion electrical equipment	4,477.26
Cyanide filter plant	14,154.92
Cyanide filter plant, proportion electrical equipment	3,040.71
Piping, pumps, etc	12,886.19
Precipitation	9,989.23
Precipitation, proportion electrical equipment	239.42
Heating plant	12,333.70
Water service	5,288.57
Water service, proportion electrical equipment	1,028.13
	$241,666.89
To this cost was added later the installation of the intermediate filtering and desulphurizing equipment, not included in original estimate	13,172.63
Total cost of mill	$254,839.52

Other construction mill work undertaken at the same time and which would have been common to either a cyanide mill or a concentrator is as follows:

Tram Lines, Washing Plant, Etc., Section

Departments	Cost to Jan. 31, 1913
Crushing, sorting, and jigging	$25,836.64
Crushing, sorting, and jigging, proportion electrical equipment	2,274.55
Meyer crushing section	5,945.98
Tram lines, aerial	18,299.05
Tram lines, Kendall	6,499.61
Fixing roads	4,386.02
Workshops	4,813.14
Proportion office and supervision during construction	1,756.26
Total cost	$69,811.25

All the ore from the various workings is delivered into the washing plant ore bins after it has been crushed to 3 in. in gyratory crushers. The ore from the northwest side of Cobalt lake is brought over in a Bleichert aerial tram line 3,560 ft. long, with a rise in elevation between the loading and unloading stations of 172 ft., the longest span being 1,080 ft., the distance across the lake. The tram line runs at 500 ft. per minute and delivers 110 six cu. ft. buckets, equal to about 35 tons, per hour, requiring 10 h.p. to operate it.

The ore from the workings on the mill side of the property is delivered by surface tram lines.

Washing Plant

There are four ore bins, each of 80 tons capacity, in this part of the mill, so arranged that all one class or several classes of ore may be sent to be milled, as conditions may require. The ore from the bins is loaded into a 20 cu. ft. car and passed over a Fairbanks registering scale, where the record is made of the total weight of ore delivered to the mill. It is then fed through a 40 in. diameter by 10 ft. long washing trommel, running at 14 rev. per minute, the screen portion of which is arranged with holes 1.5 in. in diameter. The coarse ore from the screen falls on to a 30 in. wide picking belt, from which the hand-picked portion of the high-grade ore is sorted, the low-grade portion on the belt being conveyed and delivered to the crusher, where it is broken to 1.5 in. before passing into the battery ore bin. The ore screened through the trommel flows to a washing trommel 30 in. in diameter by 6 ft. long running at 20 rev. per minute, equipped with 0.5-in. round-hole screen, the oversize from which goes to two jigs, fitted with rolled-slot screen, width of slot 0.115 in.; here the first jig portion of the high-grade ore is collected.

The undersize from this last trommel is conveyed to another trommel, 36 in. in diameter by 9 ft. long, running at 20 rev. per minute, equipped with 3-mm. round-hole screens, and from here the discards go to two jigs, fitted with rolled-slot screen, width of slot 0.040 in.; here the

second jig portion of the high-grade ore is obtained. The undersize from this last trommel, together with the discards from the four jigs, is elevated to a dewatering trommel, 30 in. in diameter by 6 ft. long, fitted with 3-mesh wire cloth screen. From this dewatering trommel the oversize joins that portion of the ore from the picking belt which is destined for the battery, while the undersize after dewatering is sent direct to join the pulp from the battery as it goes to the tube mills. This portion of the ore, representing from 10 to 15 per cent., is the original fines as they come from the mine together with some which may have been produced in the preliminary stages of crushing, and the by-passing of it around the battery in this manner has very successfully and materially assisted the battery work. The water used in the washing plant is kept continually in circulation by a 4-in. diameter centrifugal slime pump, a few pounds of lime being added to the water every day to aid the settlement of slimes, these being collected in two 12-ft. diameter by 6 ft. vats, where after settlement they flow to tube mill pulp. The power necessary to operate this plant is 35 kw. for 9 hr., during which time from 300 to 350 tons is handled.

This part of the operations followed closely along the line of previous sorting and jigging practice worked by the company and owes much of its success to H. A. Kee and his experience in this work.

The high-grade ore, which is sorted out in this part of the mill, varies considerably in quantity and grade, but an average recovery is as follows, per 100 tons treated:

	Tons	Average Value, Oz. per Ton
Hand-picked ore	0.662	2,803
First jigs	0.265	2,496
Second jigs	0.138	2,200
	1.065	2,648.47

This ore is sent to the high-grade ore mill, where it is treated by the cyanide amalgamation process described in R. B. Watson's article, a recovery of 97 per cent. being obtained by amalgamation, and a further 2 per cent. by cyaniding, or a total recovery of 99 per cent. from a 2,648.47-oz. silver ore. The residues, which contain from 8 to 9 per cent. of cobalt, are afterward sold for the value of this metal and 85 per cent. of the silver contents, so that from an ore of the above original head value, only about 4 oz. of the silver value is not paid for.

The ore after being crushed to 1.5 in. in a No. 4 gyratory crusher is transferred on a 20-in. belt conveyor into the mill building, then elevated by a 16-in. bucket elevator into the battery ore bin, which has a capacity of 780 tons. The ore is fed from the bin into the mortars by suspended Nelson feeders.

Battery

The mortar-block foundation, consisting of 846 cu. yd., is of concrete, 81 ft. long by 6 ft. wide on top, with the anchor bolts set in on an incline, and facilities are arranged for dropping the bolts so that a mortar may be easily rémoved. The battery posts are 12 by 26 in. and 24 by 26 in., set in cast-iron shoes, rubber 0.25 in. thick being placed between shoes and concrete. The mortars are Fraser & Chalmers No. 161 type for rapid discharge; they weigh with steel liners 12,410 lb. each, and have rubber 0.25 in. thick placed between them and concrete.

There are forty 1,500-lb. stamps, arranged five to each cam shaft, and the order of drop is 1, 3, 5, 2, 4, with a set height of 8 in. at 96 drops per minute. The cam shaft is a 7 in. diameter Blanton fluted type and the stems are 4 in. in diameter. The height of discharge is maintained at 1 in. above the level of the dies.

The stamps when new are made up as follows:

	Pounds
Swedish iron stem, 4 in. diameter bv 16 ft. long..........	681
Cast-steel tappet, $10\frac{1}{8}$ by 14 in., keys and gib..........	190
Cast-steel head, 9.5 in. diameter by 24 in. long..........	412
Forged chrome-steel shoe, $8\frac{1}{4}$ by 12 in. long.............	254
	1,537

Each battery of 10 stamps is driven by a 40-h.p. motor running at 575 rev. per minute. The motor is placed directly under the ore bin and drives with a 12 in. wide rubber belt to the counter shaft placed below the feeder and mortar floor. This counter shaft runs at 113 rev. per minute and is placed at 11 ft. 7 in. centers from the motor. Drive from counter shaft to cam shaft is by a 12 in. wide 8-ply belt to a 6 ft. diameter cam shaft pulley. The operation of the various battery motors is controlled by individual switchboards arranged side by side, under the battery ore bins.

The battery screens are 18 in. deep and are made of crucible cast high-carbon steel, double-crimped, wire cloth. This quality of screen has been in operation now for three months, and the screens show practically no signs of wear.

Chilled cast-iron liners 1 in. thick in the mortars last but 30 days, while manganese-steel liners last as long as 165 days. Life of shoes is 105 days, equal to 703.5 ton-days, dies being good for 130 days, equal to 871 ton-days.

The power necessary to drive each 10 stamps is 23 kw.

A dilution of about 7 of solution to 1 of ore gives the best results in the mortars while crushing.

The battery feed vat is 20 ft. in diameter by 15 ft. deep, containing

147 tons of solution, and the underside of the vat is located 8 ft. 6 in. above the top of the mortar. The main pipe installed between vat and batteries is 6 in. in diameter, and flanged connections are used between pipes, fittings, and valves to enable the easy cleaning of pipes.

On account of the preliminary desulphurizing treatment which is given to the ore before cyaniding, it is necessary to crush the ore in the battery in a 0.25 per cent. caustic soda solution, with no cyanide in it, 5 lb. of lime being added to every ton of ore as it is placed in the battery ore bin, as being necessary for the settlement of the slime in the collecting vats, enabling a clean solution to be returned for recrushing and classification purposes.

The Cobalt ores are extremely hard and tough and the following table gives some results on crushing and screening capacity:

Battery Screens and Crushing Duty

Stamps in Operation	Mesh per Inch	Size of Wire Inch	Aperture Inch	StampDuty per 24 hr. Tons
Early Practice				
20	8 by 8	0 048	0 077	5.7
20	4 by 4	0 072	0.178	
Present Practice				
20	3 by 3	0.072	0 261	6.7
20	2 by 2	0.092	0.408	

Screen Pulp Grading Mesh

+8	+20	+60	+100	+150	+200	−200 Sands	−200 Slimes
25.1	29.8	17.89	5.93	1.93	1.65	4.28	12.43

Classification and Fine Grinding

The importance of extremely fine grinding was clearly demonstrated in the early experiments, and further experimental work confirmed this. The grinding was then considered on the basis that all the ore, metallic silver included, had to be ground to pass a 200-mesh screen; then this product had to be classified to take out the −200 mesh sands for regrinding and further classification, until there remained only about 15 to 20 per cent. sand, much finer than −200 mesh, in the product delivered to the cyanide plant.

The need for an accurate method to determine the percentage and grading of these sands and slimes was soon apparent and resulted in the provision of a small system of cone classification to replace the earlier practice of hand panning. Three tin cones, respectively 5.5 in., 7 in., and 10.5 in. in diameter at the top, were arranged in series for these tests, with a water dilution vat 8 in. in diameter by 8.5 in. deep located to give a 6-in. head. The pulp to be tested is slowly fed into the first and smallest of this series of cones and the different grades of sands and slimes are recovered from each cone. This device shown in Fig. 5, works fairly accurately, so two of them were installed; thus a constant check could be kept on this work, as the final residues from the cyanide plant almost invariably rise or fall according to the efficiency of the grinding.

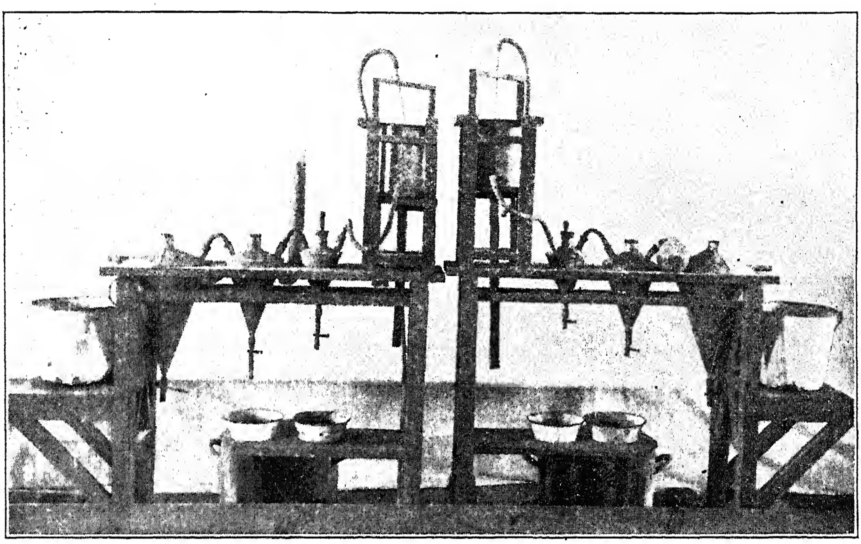

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FIG. 5.—ELUTRIATION APPARATUS IN LOW-GRADE ORE MILL.

As an instance of this, when a grading test of the mill pulp delivered to the cyanide plant shows 3 to 4 per cent. +200 mesh and 30 to 35 per cent. sands in −200 mesh, the final residue after cyanide treatment will be about 3.50 to 5.00 oz. of silver per ton. When a grading test of the pulp shows 0.5 to 1.0 per cent. +200 mesh and 15.0 to 20.0 per cent. sands in −200 mesh, the final residue after cyanide treatment will be under 2 oz. of silver per ton of ore.

The necessity for such fine grinding of the ore accounts for the large tube mill and classifier capacity as compared with the number of stamps operating. The classification is obtained in one drag classifier and six Dorr duplex classifiers, the slime-overflow lips of which were raised 5

in. to give more opportunity for the settlement of the −200 mesh sands, and prevent them from being carried over with the fine slimes as they overflow to the cyanide plant.

Tube Mills

The four tube mills are 6 ft. in diameter by 20 ft. long, with feed- and discharge-end bearings 20 in. in diameter by 18 in. long. The feed-end bearing or gudgeon is fitted with a removable, hard iron, spiral-grooved liner 9 in. in inside diameter, and to the outside is fastened the feeding device, consisting of a cast-iron spiral scoop, the inside dimensions of which are 6 by 6 in. This scoop picks up from a wooden box the pulp which is to be fed into the mill. The discharge-end gudgeon has a chilled cast-iron screen with 0.5 in. diameter holes in it to retain the pebbles inside the mill. The shell of the mill is $\frac{9}{16}$ in. thick, and Silex bricks 4 in. thick are used for inside lining. There are two 18 by 18 in. man-holes. The mills run at 25 rev. per minute and are driven by pinion and spur gears of 100 and 15 teeth, 3.5 in. pitch and 12 in. face, from a counter shaft to which the 96 in. diameter by 19 in. face driving pulley is connected through a quill and friction clutch. The weight of the shell of the mill is 9,650 lb. The weight of the two cast-steel heads, $1\frac{5}{8}$ in. thick, is 12,000 lb. The total weight of each mill is 45,375 lb.

The mills are arranged parallel to each other and at right angles to the battery, the driving, shafting, and gears being arranged at the feed end of the mill. Each mill is driven by a 125-h.p. motor, running at 580 rev. per minute, the motor pulley being 28 in. in diameter and 19 in. face and driving to the 96 in. diameter pulley on the counter shaft.

Two of the mills with their motors are located at 19 ft. 4 in. centers and the other two at 24 ft. 4 in. centers, the drive being transmitted through 18 in. wide eight-ply endless stitched rubber belting.

This system of driving has been very satisfactory, none of the belts after 12 months' continuous service having yet been cut or spliced. The power necessary to drive each mill is 85 kw. when they are carrying a pebble load about 2 to 3 in. above the center of the mill. The mills operate in a closed circuit, two of them taking the classified pulp from the battery and the other two taking the classified fine sands for regrinding.

The two coarse-grinding tube mills are charged with flint pebbles and a hard-ore pebble, selected from the hardest portion of the run-of-mine ore, and the average consumption of pebbles in these two mills per ton of ore crushed is about 1.8 lb. flint pebbles plus 2.0 lb. of ore pebbles. The two fine-grinding tube mills are charged with only flint pebbles and the average consumption of pebbles in them per total ton of ore crushed is about 4.3 lb., thus giving a total flint pebble consumption of 6.1 lb. plus 2 lb. of ore pebbles.

The best grinding efficiency is obtained in all mills when the pulp carries about 40 per cent. of solution.

The following data give the particulars of the feed and discharge of the mills when operating on the basis of 244 tons per day:

	Two Tube Mills on Coarse Grinding fed by four Duplex Dorr Classifiers, each Classifier handling about 61 Tons in 24 Hr.				Two Tube Mills on Regrinding fed by two Duplex Dorr Classifiers and 1 Drag Classifier			
	No. 3 Mill.		No. 2 Mill		No. 1 Mill		No. 4 Mill	
Mesh	Head Sample or Feed to Mill	Tail Sample or Discharge	Head Sample	Tail Sample	Head Sample	Tail Sample	Head Sample	Tail Sample
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
+20	57.02	5.8	58.89	2.90	2.12	0.4	4.46	1.44
40	14.7	5.58	14.74	4.96	1.90	0.92	3.86	0 70
60	5.17	6.04	6.82	7.6	2.44	1.00	5.38	1.56
80	4.26	6.24	4.19	8.96	5.06	7.77	6.60	3.80
100	4 73	9.2	4.10	11.32	12.06	2.74	11.34	10.40
120	3.48	7.6	2.47	6.96	11.14	6.46	2.40	9.80
150	0.30	0.40	0.27	5.0	1.42	0.4	3.92	0.62
+200	3.44	6.86	1.43	8.9	18.40	12.90	18.0	4.38
−200 Sand	5.21	19.30	5 28	18.11	41.19	38.27	39.94	38.44
−200 Slime	1.67	32.18	1.58	24.73	3.11	28.23	3.02	28.16
Totals	99.98	99.20	99.77	99.44	98.84	99.09	98.92	99.30

The battery pulp is conveyed to and classified in the first set of four classifiers, the slimes overflowing direct to the slime collecting tanks in the cyanide plant, and the oversize from all four is delivered into the two coarse-grinding tube mills. The table shows the grading of the product fed into these mills.

The discharge from the coarse-grinding tube mills flows into the second set of two Dorr classifiers, where it is again separated into slimes and sands; the slimes overflow into the same slime collecting tanks and the sands are elevated to the two fine-grinding tube mills. The table shows the grading tests of these mills.

The discharge from the fine-grinding tube mills flows into the drag classifier and the above set of two Dorr classifiers; the slimes overflow to collecting tanks and the sands are returned for further fine grinding.

In this system all sands and metallic silver are kept in a closed circuit until they have been ground fine enough to overflow the weirs of the classifiers, and on account of the fine product desired, the weirs were raised and the capacity of these standard classifiers was very much reduced, so as to give more opportunity for settlement.

The best classification is obtained when working with a dilution of about 8 of solution to 1 of ore, and frequent sampling of the slime overflow is necessary to insure that not overmuch fine sands are passed over to the collecting tanks.

Tonnage and Values

All the ore is weighed into the mill over a Fairbanks registering scale, a simple and effective method of obtaining the tonnage. These weights are then checked against the usual method of specific gravity tonnage determination made in the slime plant, and after a seven months' mill run there was a variation of only one-eighth of 1 per cent. in favor of the specific gravity tonnage.

Many moisture determinations have been made on a large scale on the ore as it comes into the mill and the average shows 1.5 per cent. of moisture during the summer months and 2.0 per cent. during the winter months.

The head assay value is taken by an automatic sampler, the slotted pipe of which cuts vertically through the mill pulp, about every 6 min. as it comes into the cyanide plant. The ore in the pulp at this stage has all been crushed to finer than 200 mesh in a caustic soda solution, with no cyanide in it, so that this method insures as correct a sample as it is possible to get.

The residue sample is taken while the filter box is being discharged, a number of cuts of the pulp being taken from each discharge opening and then all mixed together.

On the basis of these determinations a check has been kept on the silver bullion being produced, and although a final clean-up will not be taken until the end of the year, yet already more silver is being produced than the commercial assaying of the ore calls for, which warrants the consideration of the difference between the commercial and the corrected assay values of the ore.

The pulp as it flows from the classifiers in the crushing department into the cyanide plant has a dilution of 11 of solution to 1 of dry slime.

Launders

Launders around the mill are all built of 2-in. dressed dry white pine.

From battery to Dorr classifier, carrying a pulp ground to a 2 mesh

in a 7 to 1 dilution, 9 in. wide by 7.5 in. deep, inside dimensions, on a 15 per cent. grade. The bottom of this launder is lined with a chilled cast-iron liner $\frac{5}{8}$ in. thick, the wear and tear on which after 12 months' operation has only worn off $\frac{1}{8}$ in. from the thickness.

Oversize from classifiers to tube mill feed, carrying a pulp diluted to 40 per cent. for tube mill grinding, 4 in. wide by 8 in. deep, the bottom being lined with $\frac{3}{16}$ in. thick sheet iron. The launder feeding the coarse-grinding tube mills has a 30 per cent. grade and the one feeding the fine-grinding tube mill has a 23 per cent. grade.

Discharge from tube mills to lower classifiers, carrying the tube mill pulp diluted to about 10 to 1, 6 in. wide by 12 in. deep on a 6.25 per cent. grade, and lined with $\frac{3}{16}$ in. thick sheet iron on bottom.

Overflow from all classifiers to slime collecting vats, carrying an all-slime product, diluted about 11 to 1, 9 in. wide by 8 in. deep on a 4.7 per cent. grade.

Overflow from slime collecting vats to lower battery solution vat, carrying solution, 9 in. wide by 12 in. deep on a 5.5 per cent. grade.

Transferring slimes into any cyanide treatment vat, taking delivery from a 7 in. diameter centrifugal pump of 1,000 gal. per minute, diluted 1.5 solution to 1 slime, 22 in. wide by 18 in. deep on a 3.1 per cent. grade.

Transferring slimes into any cyanide treatment vat, taking delivery from a 4 in. diameter centrifugal pump of 230 gal. per minute, diluted 1.5 solution to 1 slime, 11 in. wide by 12 in. deep on a 3.1 per cent. grade.

Decanted solution from cyanide treatment vats, from a 6 in. diameter decanter under a 13-ft. head, 19 in. wide by 15 in. deep on a 1 per cent. grade.

Cyanide Plant

This part of the mill is placed in a building apart, but connected to the battery and tube mill building. It is arranged in two floors, the upper one containing all the slime collecting and the cyanide treatment vats and the lower floor containing all the solution vats, slime filters, and pumps. The slime treatment vats are shown in Fig. 6.

There are on the upper floor:

Three 34 ft. diameter by 13 ft. deep slime collecting vats.
Seven 34 ft. diameter by 13 ft. deep slime cyanide treatment vats.
Two 34 ft. diameter by 13 ft. deep stock slime pulp vats for charging filters.
One 34 ft. diameter by 13 ft. deep barren solution vat.

These vats are placed in two parallel rows, and, with the exception of the solution vat, they are all fitted with a mechanical stirring apparatus, driven by a line shaft placed over the vats on a wooden bridge or trestle. The paddles in the vats are made of 4 by 6 in. pine on edge and

the two longest arms are 27 ft. in diameter and revolve at 8 rev. per minute, giving a speed on the end of 678 ft. per minute; paddles are located at 2 ft. from the bottom of the vat.

These 12 vats are driven by a 125-h.p. motor, and as on an average 8 of them are agitating at one time, the power necessary to drive vats and shafting is 55 kw. Each vat has an average working load of about 140 tons of dry slime plus about 280 tons of solution.

The slime collecting vats are arranged with a circular overflow around the top on the inside, 6 in. wide by 8 in. deep, over which the

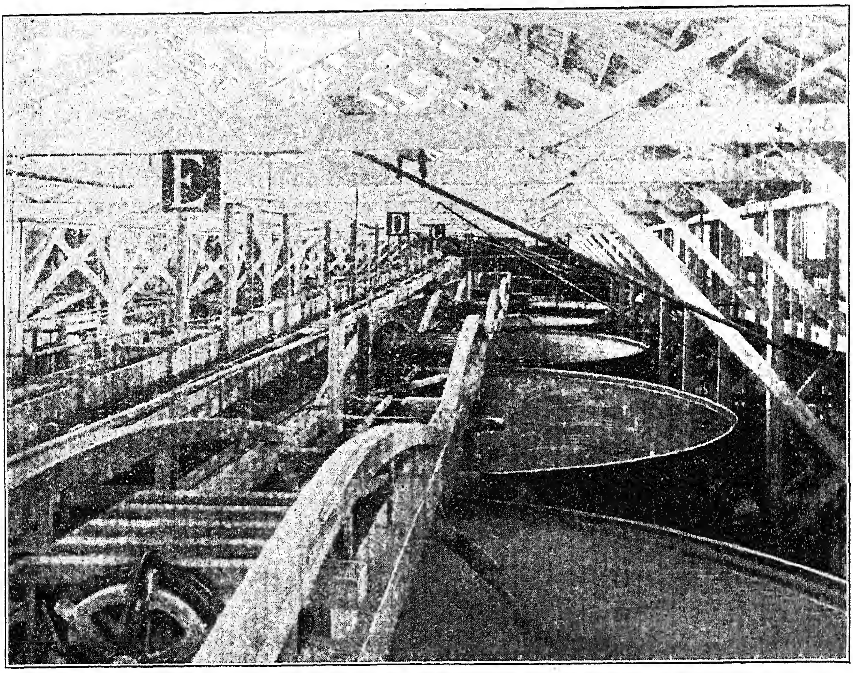

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FIG. 6.—SLIME TREATMENT VATS IN LOW-GRADE ORE MILL.

clear battery solution flows into the launder leading to the lower battery solution vat. The bottoms of the vats are connected to a 7 in. diameter and to a 4 in. diameter centrifugal pump for transferring the thickened pulp, and a 6 in. diameter decanter is fitted to the side of the vat.

The battery pulp is run into one of these vats for about 9 hr., collecting about 92 tons (dry weight) slimes, and during this collecting period the excess solution overflows to the lower battery solution vat, from which it is repumped for circulation in the battery solution circuit. When the necessary charge is collected, the pulp is switched to collect in the next vat and in the meantime the slime is settling, excess solution

being decanted until the pulp in the vat represents about 1.5 solution to 1 slime. The pulp is now agitated for about 1 hr., the depth of pulp measured, sampled, and specific gravity determination made for slime tonnage. The specific gravity of dry slimes on this ore is 2.7. The calculation made here, as previously noted, works out at practically the same tonnage as the weighed-in weight of the ore, after due allowance has been made for the addition of lime and tube mill pebbles.

The thickened pulp of 1.5 caustic soda solution at 0.25 per cent. strength and 1 of slime is now pumped to the desulphurizing treatment.

Desulphurizing Process

The problem of working out a successful all-cyanide treatment for the Cobalt ores, in which there is such a varying amount of complex minerals, led to the discovery, during the period of experimental work, of what is now known as a wet desulphurizing process. The details of the reactions involved and the necessity for such a treatment will be obtained by referring to J. J. Denny's article. Briefly explained, the preliminary desulphurizing treatment breaks up the refractory silver minerals when the slime pulp is brought into contact with aluminum in a caustic soda solution, the silver being left in a spongy metallic state readily amenable to cyanide treatment.

The desulphurizing is accomplished by passing the slime pulp through a revolving tube mill, in which there is a quantity of aluminum, and a further treatment is given in a vat lined with aluminum plates, in which the pulp is slowly agitated.

The practical effect of this preliminary treatment on the ores has resulted in the same and sometimes a better extraction being obtained in 48 hr. cyanide treatment than was otherwise obtained in 120 hr. cyanide treatment with no desulphurizing. In some of the ores which contained a greater proportion of the refractory minerals a better extraction of from 1 to 4 oz. per ton is obtained when desulphurized and cyanided, as compared with a cyanide treatment and no desulphurizing.

A tube mill, 4 ft. in diameter by 25 ft. long, lined with 2 in. thick Silex blocks, is used for the first stage of the desulphurizing treatment. This mill revolves at 10 rev. per minute and carries a load of about 4,000 lb. of aluminum ingots, cut up into cubes about 1.5 to 2 in. The slime pulp is fed through this mill at the rate of 14 tons of dry slimes per hour, diluted with 1.5 caustic soda solution to 1 dry slime. The pulp then gravitates into the 34 ft. diameter by 13 ft. deep alkali stock pulp vat, which is arranged with mechanical agitation and lined around the side with aluminum plates. The pulp is agitated in this vat about 24 to 36 hr., or until it is gradually drawn off in about 40-ton charges to the dewatering filter box. On account of keeping the mill cyanide solution

in balance, it is necessary to eliminate as much as possible the crushing caustic soda solution from the slimes before they are transferred into the cyanide vats for treatment, and this is done in a Butters filter plant equipped with 60 leaves, which is capable of dewatering 270 tons of slimes per day, the cake when discharged carrying 26 per cent. alkali solution as moisture.

The slimes after dewatering flow into a 16 ft. by 5 ft. deep pulping vat, where they first come in contact with cyanide solution, being diluted with about 2 of cyanide solution to 1 of slime, a 4 in. diameter centrifugal pump being used for transferring the pulp into the cyanide treatment vats.

Cyanide Department

There are seven, 34 ft. diameter by 13 ft. deep slime treatment vats, fitted with mechanical stirring arrangement. Each vat has a 6 in. diameter decanter, for draining off the clear settled cyanide solution; they are also fitted with a 6 in. diameter air lift operated by a 0.75 in. diameter pipe with air at 20 lb. pressure.

The slimes are treated in charges of about 130 tons dry slimes in a vat, with a dilution of 2 of solution to 1 of dry slimes in a 0.25 per cent. cyanide solution and 0.20 per cent. alkali, agitation being maintained for 48 to 60 hr. Repeated testing in the mill has demonstrated that equally as good an extraction of the silver values is obtained with a 2 to 1 dilution as with a 3 to 1 dilution. The air lift is operated all the time the charge is being treated, so that there is a possible turning over of the charge about 16 times by the air lift.

After the agitation treatment, the charge is allowed to settle, so that the clear solution may be decanted to the pregnant solution vat. The pulp is then agitated and transferred by a 7 in. diameter centrifugal pump to the 34 ft. diameter by 13 ft. deep cyanide stock pulp vat, in which it is kept agitated until drawn off into the filter box.

A Butters filter plant equipped with 80 leaves handles 35- to 40-ton charges in about 3 hr. each, the slimes being discharged with 26 per cent. of moisture. The alkali and the cyanide filters are arranged alongside of each other, Fig. 7, so that the same operator handles both boxes from the switchboard placed between them. The filter plants are arranged on the semi-gravity plan; a 10 in. diameter centrifugal pump with 12 in. diameter suction and delivery pipes and hydraulically operated valves is connected with the cyanide box for transferring the excess pulp and solution wash. The clear solution from the cyanide filter box is delivered to the pregnant solution vat and the residue slime is dropped into the empty box, discharging by gravity to the residue dump.

The alkali filter box is connected to an 8 by 10 in. duplex double-

acting piston vacuum pump with a displacement of 340 ft. per minute at 160 rev. per minute. The cyanide box has a 12 in. diameter by 10 in. stroke duplex double-acting piston vacuum pump with a displacement of 770 ft. per minute at 160 rev. per minute.

The pregnant solution vat is 34 ft. diameter by 8 ft. deep and the barren solution vat is 34 ft. diameter by 13 ft. deep.

Precipitation Department.

The original plans of this section of the mill were laid out with the intention of using zinc dust for precipitation and an equipment was in-

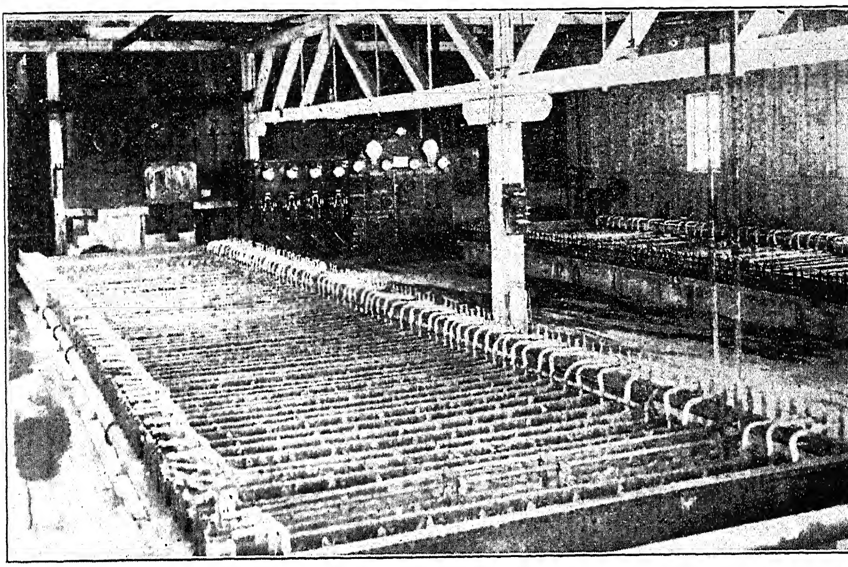

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FIG. 7.—BUTTERS SLIME FILTER PLANT IN LOW-GRADE ORE MILL.

stalled of one 20-frame and one 10-frame 52-in. Merrill precipitation presses with 3-in. frames, together with the other necessary machinery.

Before the mill was ready to start, the experimental work on the use of zinc dust as a precipitant had disclosed that the cyanide solutions after precipitation rapidly deteriorated and fouled, so as to lose their dissolving efficiency. The investigation on this subject has been very fully explained in E. M. Hamilton's and J. J. Denny's articles and proves how impossible it would be to use zinc dust and get good results. After considering various other methods of precipitation, it was decided to use aluminum dust as the precipitant and modify the equipment accordingly.

The practical benefits gained by this change are:

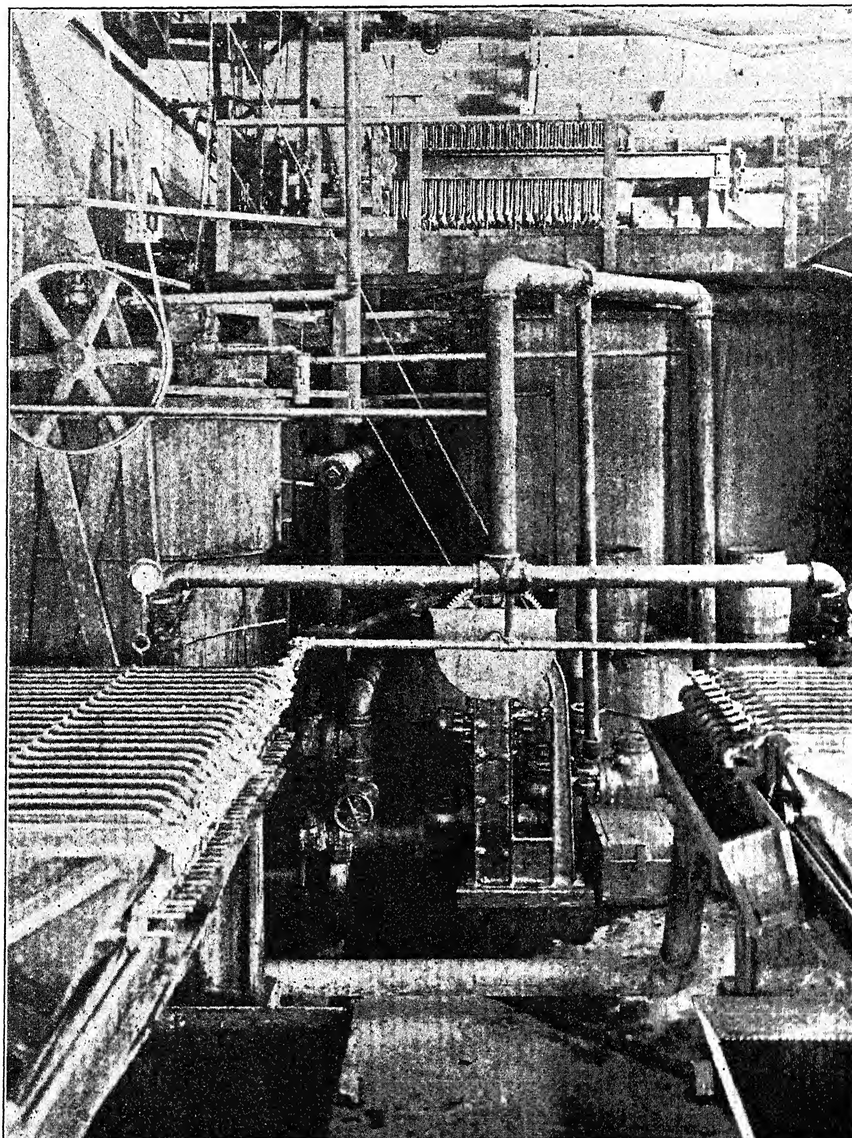

FIG. 8.—ALUMINUM DUST PRECIPITATION PLANT IN LOW-GRADE ORE MILL.

No fouling of cyanide solutions, with a corresponding reduction in dissolving efficiency.

The working mill cyanide solutions are in a more active condition to dissolve silver than if they were freshly made up solutions which had not yet been used, showing in their favor an increased dissolving power of 0.35 oz. of silver per ton of ore.

A regeneration of 0.608 lb. of cyanide per ton of solution precipitated, equal to about 1.67 lb. of cyanide per ton of ore treated, or 408 lb. per day.

The recovery of silver precipitates averaging about 27,000 oz. per ton, or about 93 per cent. silver.

The pregnant solution is pumped to the precipitation room by a 6 by 9 in. vertical triplex pump, running at 54 strokes per minute, where it is clarified in a sand filter before flowing to the special tank arrangement for mixing the aluminum dust in the cyanide solution. It is then pumped into the precipitation presses by another 6 by 9 in. vertical triplex pump. The 20-frame press takes about four days to fill up with precipitates when handling about 550 to 600 tons of solution per day with a head assay running about 8.25 oz. and a tail assay 0.10 oz. The aluminum dust consumption over a nine months' period averages about 0.556 lb. per ton of ore treated, or 1 lb. (avoir.) dust = 45.26 oz. (troy) silver precipitated, or 1 lb. (avoir.) dust = 3.104 lb. (avoir.) silver precipitated. The precipitates are sent to the refinery, where they are melted and refined in a reverberatory furnace, as described in R. B. Watson's article, and eventually shipped as bullion at 997 to 999 fine.

Fig. 8 shows the precipitation plant.

For the aeration of the cyanide treatment solutions and for use on filters and air lifts, there is installed an 18.25 in. diameter by 12-in. stroke belt-driven air compressor, with a piston displacement of 627 cu. ft. of free air per minute at 20 lb. pressure, running at 180 rev. per minute.

The heating plant is of the gravity type and is located 80 ft. away from the main mill building, the boilers being placed so that the water level in them is 5 ft. below the lowest floor level of the mill. There are two horizontal multitubular boilers, 72 in. in diameter by 16 ft. long, working at from 0 to 10 lb. steam pressure, with a 10 in. diameter steam line and a 5 in. diameter return water line between the boiler shed and mill building.

	Radiators	Heating Surface, Square Feet
Mill building	57	8,092
Washing plant	13	1,971
Vat shed	4	251
Total	74	10,314

In addition to this, there is about 40 per cent. more heating surface in all the distributing steam pipes around the mill.

This heating plant has maintained an average temperature of about 60° F. in the coldest weather, which is sometimes down to 40° below zero.

Extraction

The following figures represent the average extraction obtained from a run-of-mine ore of 54 oz. of silver per ton, in the combined metallurgy of the high-grade and low-grade ore mills:

	Heads per Ton		Total Silver	Extraction	Average Residue per Ton	Total Residues
79 tons of	2,648 47 oz.	=	209,229.13 oz. at	99%	26 484 oz. =	2,092.29 oz.
7,320 tons of	26 00 oz.	=	190,320 oz. at	92%	2 080 oz. =	15,225 60 oz.
7,399 tons	54.00 oz.			95 66%	2.34 oz.	

To this will be added the further recovery of 85 per cent. of the silver, made on the sale of the above 26.484 oz. of residue.

The working mill costs are here represented in the percentage that the various most important expenses bear to the total cost.

	Per Cent.
Labor	28.207
Cyanide	19.943
Electric power	14.542
New construction supplies	5.586
Aluminum dust	4.761
Aluminum ingots	4.709
Caustic soda	1.811
Aluminum plates	1.401
Refinery fluxes, fuel oil, coke, etc	1.332
Pebbles	1.284
Battery supplies	1.013
Lime	0.579
Sundry supplies	14.832
	100.000

Operating Costs per Ton of Ore Treated; Average for the Months of July, August, and September, 1913

Costs calculated on basis of 7,320 tons treated per month

	Labor	Supplies	Power	Work Shops	Totals
SUNDRY COSTS PER TON					
Meyer receiving plant	$0.049	$0 002	$0.003	$0.001	$0.055
Aerial tram line	0.059	0.004	0.003	0.009	0.075
Surface tram line	0.073	0.045	0.005	0.027	0.150
Washing, jigging, and picking plant	0.138	0.042	0.006	0.024	0.210
Totals	$0 319	$0.093	$0 017	$0.061	$0 490
New construction	$0.036	$0.209	....	$0.065	$0 310
MILLING COSTS PER TON					
Preliminary crushing to 3 in.	$0.074	$0.004	$0.006	$0.002	$0.086
Secondary crushing, conveying, and elevating	0.028	0.015	0.005	0.001	0.049
Battery	0.077	0.053	0 095	0.013	0.238
Tube mills and classifiers,	0.096	0.103	0.282	0.019	0.500
Slime collecting, desulphurizing, and transferring	0.042	0.294	0.022	0.008	0.366
Alkaline, filtering and transferring	0.070	0.017	0.023	0.004	0.114
Cyanide treatment and transferring	0.120	0.793	0.071	0.020	1.004
Cyanide filtering and discharging	0.072	0.041	0.034	0.015	0.162
Clarifying solutions and precipitation	0.050	0.221	0.008	0.005	0.284
Drying, melting, and refining	0.074	0.050	....	....	0 124
Water supply	0.001	0.001	0.021	0.002	0.025
Totals	$0.704	$1.592	$0.567	$0.089	$2.952

Electrical Power

In a mill where the average power costs represent about $4,000 out of a total working cost of about $28,000 per month, it was advisable to arrange the installation so that as high an efficiency as possible might be obtained.

The installation was so planned that each machine should be of the correct size to carry its load, and thus obtain the highest efficiency and power factor.

As a measure of the success obtained in this respect it may be stated that the power factor of the mill averages 82.5 per cent.

Original Motor Power Distribution

	Motors	Horse Power	Rev. per Minute	Total Horse Power
Washing Plant· operates 6 days of 9 hr. each, per week:				
Main drive	1	40	850	
Aerial tram line	1	15	565	
Surface hoist	1	30	720	
Elevator hoist	1	10	900	95
Battery:				
Battery drive	4	40	575	
Return solution pump	1	40	575	
Elevator ore bin	1	10	1,120	
Conveyor belt	1	5	1,800	215
Tube Mills:				
Mill drive	4	125	580	
Lower classifiers	1	5	1,120	505
Treatment:				
Agitating tanks	1	125	485	
Circulating slime	1	35	855	
Circulating desulphurizing	1	20	690	
Alkali pump to cyanide tanks	1	20	690	
Experimental plant	1	2	1,800	202
Two Filters:				
Filter box—cyanide	1	80	870	
Filter box—alkali	1	35	855	
Vacuum pump—cyanide	1	10	570	
Hydraulic valves	1	1	1,200	126
Precipitation	1	10	570	10
Water Service:				
Centrifugal pump	1	25	1,800	25
	27			1,178

Cost of installation, $24.15 per horse power of motors

Cost of Electrical Installation

Motors, switchboards, wiring, etc., and labor	$26,532.86
Electric lighting of mill	1,635.61
	$28,168.47
Extra wiring, poles, etc., for the Peterson Lake pumping plant, located about 1,560 ft. from the main buildings	250.00
	$28,418.47

Power is received at a pressure of 11,000 volts and is transformed to the working pressure of 550 volts in a substation situated 150 ft. from the

main building. A three-phase overhead line from this substation feeds the main switchboard, which is placed on the tube mill floor, this position being about the center of power consumption.

From the main board, feeders are carried through suitable links and disconnecting switches to the various motor control boards.

The motors are all three-phase 550 volts 60-cycle Canadian Westinghouse type G.M. machines. The "squirrel cage" rotor was selected on account of its ruggedness and simplicity. The average full-load efficiency and power factor for each class of these machines was found after careful testing to be:

	Efficiency, Per Cent.	Power Factor, Per Cent.
125-h.p. class..............	91.0	89.6
80-h.p. class..............	89.0	88.0
40-h.p. class..............	88 3	86.9
35-h.p. class..............	87.5	83.6
15-h.p. class..............	85.8	85.5

Each motor is provided with a control panel upon which are mounted a three-pole automatic oil circuit breaker, an auto-starter, fitted with no-voltage release, an ammeter, and a serviceable inverse time-limit relay in the form of fuses and a double-pole spring tumbler switch, inserted across the circuit breaker tripping coil terminals. This relay is used for starting duty only, and in conjunction with the no-voltage release on the auto-starter, renders the gear practically "fool-proof." The motor control panels, 1 ft. 6 in. wide by 6 ft. high, are grouped to make switchboards of convenient size, and are so placed that the machines which they control may be easily seen from them.

The main switchboard is equipped with an automatic three-pole oil circuit breaker, controlling the entire mill supply, a voltmeter, an ammeter, an integrating wattmeter, and a graphic recording wattmeter. The wiring of the graphic wattmeter is so arranged that a record of either the total mill load or the load of any individual motor may be obtained.

All wiring within the mill is carried in steel conduits. The average total load on the mill amounts to 690 kw. The recording wattmeter registers a variation of less than 5 per cent. from this figure from day to day, on the day load.

Much credit is due to W. H. R. Burrows, the company's resident engineer, for the excellent installation and high efficiency obtained in this power service.

In conclusion, I wish to acknowledge the encouragement and assistance of R. B. Watson in the many difficulties that developed before everything was satisfactorily worked out, and his permission to publish the data in this article; also to put on record the good work done by Mr. Hamilton and Mr. Denny both during the experimental work and during the starting up of the mill.

Discussion

Chairman E. Gybbon Spilsbury.—I would like to call attention to the fact shown in this paper that less than five years or perhaps seven years ago nobody had thought it possible to cyanide with success silver ores. The cyaniding of silver and gold ores was first of all started in Mexico, and gradually extended to this country in the case of the silver ores alone. The average extraction, I think, for the metals in Mexico, in the case of the silver ore, is less than 85 per cent., whereas here, in the case of a very complex ore, carrying a high percentage of sulphur and arsenic, and other objectionable elements, the ore has been treated so as to extract an average of 95 per cent. of the silver contents of the ore. It is really a phenomenal revolution in the metallurgy of silver ores which has been demonstrated and worked out at the Nipissing mines.

George A. Packard, Boston, Mass.—I would like to suggest a slight modification, perhaps, of the statement which is made that no one considered cyaniding of silver ores up to five, or perhaps seven years ago, because in 1897, when I was at Mercur, Utah, one mill near there was operating on silver ores. It did not operate very successfully from a commercial standpoint, because they did not have a great deal of ore, but the extraction, I was told, was very satisfactory, and I am quite confident that it was, because, as suggested by the name, Chloride Point, the ores were silver chloride ores, and of course very easily soluble. Some years before that, in 1892, I made some tests myself. I spent three months making tests on more or less complex silver sulphide ores at Virginia City, Mont., and while our tests on the plain sulphide ores, finely ground, were quite successful, on account of the presence of a small amount of copper we did not work out a satisfactory solution of the problem at that time; although since then a cyanide plant has been erected and for at least eight years these ores have been treated by cyaniding at Virginia City, and the mill is still in operation. The period of five to seven years should, therefore, be modified considerably, in justice to the pioneers in the cyanide processes.

Reginald E. Hore, Toronto, Ont., Canada.—I hoped that there would be metallurgists from Cobalt here to present and discuss Mr. Johnston's paper. In their absence a few remarks from me may help to make clearer to you what they have accomplished.

When the mining activity at Cobalt began, it was recognized that the ore was a very difficult one to deal with. The valuable mineral is chiefly native silver occurring in particles entangled in a mixture of smaltite, niccolite, calcite and other minerals. Much of the ore is very profitably smelted, even though little or no profit is made on the cobalt, nickel, or arsenic contained in it.

Soon it became evident that a process must be devised to treat the low-grade ore. Concentrating mills were built and were successful in treating profitably much of the low grade. There was, however, difficulty in making an economical recovery of the last 5 or 6 oz. per ton. After a little experience with milling, many who were especially familiar with cyaniding processes experimented on these silver ores. At the Buffalo mill the cyaniding treatment was used. It worked fairly well. Only the slimes were treated, most of the silver being recovered by concentration. At the O'Brien and Nova Scotia mills cyaniding treatment was introduced early. In the case of some of the ores the cyaniding of silver worked fairly well, though not remarkably well. Managers of other properties, profiting by the experiences at the Buffalo, O'Brien, and Nova Scotia mills, left it pretty much alone. Straight concentration was found in many cases to be more satisfactory.

The silver in the high-grade ore is chiefly native silver. The low-grade ore has a lot of filmy sulphides as well as native silver occurring in the crevices of the fractured rocks on either side of the high-grade veins. The silver in the sulphides and antimonides was not easily saved.

There was for some time a very decided difference of opinion as to whether it was worth while to cyanide the Cobalt silver ores. The great success of the straight concentration method was evident—there were good mills working, the Coniagas and Northern Customs, for instance.

Among the most remarkable improvements in metallurgical methods at Cobalt is the amalgamation-cyanidation of the high-grade ores. This is a distinctly new method of winning silver from ores. The high-grade ore is treated with mercury in a tube mill and a wonderful recovery is made in that way.

One of the difficulties of treating the sulphides in the low-grade ores was overcome by the process devised by J. J. Denny, which is referred to in the paper as a desulphurizing process. Another important feature is the use of aluminum dust for precipitation, a process which was introduced in Cobalt by S. F. Kirkpatrick, of the School of Mining, Kingston. Since these processes have been adopted the cyaniding of low-grade ores has been more successful. In brief, it was found that some low-grade ore could be worked and milled quite profitably without cyaniding, but low-grade ores which contained considerable sulphides were costly to treat until the new process was devised. Desulphurizing by aluminum and precipitation by aluminum are important features at the Nipissing plant, which is so creditable to the metallurgists who have been connected with it and which has been so well described by Mr. Johnston in the paper now before us.

W. A. Caldecott, Johannesburg, So. Africa (communication to the

Secretary*).—This detailed article on Nipissing ore-treatment methods is of special interest to the writer, both on account of his association with Messrs. Butters and Johnston in their earlier metallurgical work in South Africa, and also on account of his visit under the auspices of the Institute to the Nipissing in 1907, when the treatment of such low-grade ore was an unsolved problem, and when in fact the most prominent metallurgical appliance in Cobalt camp was a cobbing hammer.

The authors must be congratulated on the practical success of their striking innovations, such as crushing in 0.25 per cent. caustic soda solution and the use of aluminum, and these departures illustrate once more the necessity of modifying known methods to correspond with the conditions of new problems.

The use of 1,500-lb. stamps with ½-in. mesh screening, and a ratio of ten stamps per tube mill, is in accordance with the latest South African practice, although the weight of the stamps is a mean between those installed in recent Rand mills and those in general use in the United States. No doubt the low stamp duty of 6.7 tons is due to the hard and tough nature of the ore. The water ratio, however, of 7 to 1 in the battery screen pulp and of 11 to 1 in the final slime pulp overflow seems high as compared with the 5 to 1 practicable here, and entails additional classifier capacity and pumping.

In view of the fact that the −200-mesh sand requires regrinding, it is possible that 260-mesh (0.0023 in. aperture) screening, now commercially obtainable and in use here, could be used with advantage in the grading analysis, as a sample containing, say, 2.6 per cent. +200 may show 13.1 per cent. +260.

It is probable that the crushing efficiency of the large tube mills employed would be materially increased if fed with double or treble the present tonnage of sand per 24 hr., so as to provide sufficient coarse particles to fully utilize the impact of the falling pebbles near the discharge end.

It is not clear from the paper why the high-grade ore is subjected to the treatment detailed in the paper, since the total residue, assaying 26.484 oz. per ton, is sold and presumably smelted, which treatment might be applied to the ore in the first instance.

* Received Apr. 3, 1914.

Mining and Mining Methods in the Southeast Missouri Disseminated-Lead District.

BY H. A. GUESS, FLAT RIVER, MO.

(New York Meeting, February, 1914.)

INTRODUCTION. HISTORY AND PRODUCTION STATEMENTS.

SOUTHEAST Missouri is the oldest of the large producing districts of the United States. The first recorded production from disseminated ores was in 1869, although for many years prior to that time lead had been mined from shallow pockets, and steady growth in production has been shown ever since, the greatest increases being during the past five years.

The production by years for each of the operating companies from 1869 to 1907, inclusive, is given in Table I. In Table II. is given the production by years from 1908 to 1912, inclusive, for the district as a whole, showing the tonnage of crude ore mined, yield in concentrates, average assay of concentrates; yield in metallic lead both per ton of crude ore and in total; also approximate value of the yearly production.

It is interesting to note that the production for the 5-yr. period 1908 to 1912, inclusive, is practically equal to the total previous production, viz., the 39-yr. period 1869 to 1907, the summary being as follows:

Period.	Lead Production.	
	Tons Concentrates.	Gross Value.
1869–1907, inclusive	1,202,606	$59,869,354
1908–1912, inclusive	1,042,553	58,914,260

[a] TABLE I.—*Production of the Lead Mines of the Bonne Terre,*

Compiled from various sources.

Year	St. Joseph Lead Co.		Desloge Lead Co.		Desloge Consolidated Lead Co.		Flat River Lead Co.		St. Louis Smelting & Refining Co.		Doe Run Lead Co.	
	Tons Concentrates.	Value	Tons Concentrates.	Value.	Tons Concentrates.	Value.	Tons Concentrates	Value.	Tons Concentrates.	Value.	Tons Concentrates.	Value.
1869	161	$36,540										
1870	323	40,052										
1871	859	95,968										
1872	1,060	116,600										
1873	1,080	118.000										
1874	1,295	141,725										
1875	1,963	210,432										
1876	2,436	257,242										
1877	2,051	169,002	928	$76,467								
1878	2,819	153,354	1,843	100,259								
1879	3,565	228,160	2,332	149,248								
1880	4,254	323,304	3,531	268,356								
1881	5,317	348,795	4,646	314,778								
1882	7,304	556,028	5,903	443,906								
1883	5,952	380,928	6,770	509,004								
1884	6,804	381,034	7,530	421,680								
1885	9,769	593,955	5,458	331,846								
1886	7,372	530,784	4,542	327,004								
1887	7,387	508,226										
1888	13,027	1,042,160	The a	bove min	es						2,900	$232,000
1889	13,600	783,360	were	at Bonne							5,243 5	302,026
1890	13,851	952,000	Terre	and in 188	7.						5,516.4	280,000
1891	14,114	1,094,381	were	purchase	d.						4,219	217,600
1892	13,474	896,098	by St	Joseph							3,348	124,700
1893	14,421	587,012	Lead	Co.							3,593 3	150,000
1894	18,089	763,279			2,250	$67,500	750	$22,500			4,509.3	190,000
1895	20,411.5	563,910			4,200	126,000	Pur	chased			5,700	201,800
1896	21,908.5	659,451			4,650	129,732	by S	t. Louis			10,342	311,294
1897	23,087	563,867			5,200	158,600	Sm	elting &			12,632	343,595
1898	20,342.5	798,454			9,327	366,084	Refi	ningCo.			12,400	487,093
1899	20,024.5	844,033			10,044	490,000					12,290	518,189
1900	18,174	823,282			14,929	477,371			3,064	$122,223	19,075	906,882
1901	23,417	943,722			7,497	300,000			10,954	448,521.5	16,532	804,961
1902	26,783	918,668			9,950	417,900			17,534	664,123	17,030	810,350
1903	28,481	1,381,328			9,449	400,000			16,701	704,782	19,420	946,548
1904	28,417	1,059,158			12,742	555,359			15,511	698,002	19,100	933,839
1905	30,588	1,529,435			13,488	661,864			17,528	876,404	19,300	1.001,476
1906	43,907	2,853,966			11,641	773,320			18,503	1,086,242.6	20,032	1,315,051
1907	33,000	2,103,837			10,051	633,236			16,391	1,040,845.1	19,670	1,281,878
Total	510,988	$26,357,453	43,483	$2,942,648	125,418	$5,556,966	750	$22,500	116,186	$5,641,143.2	232,852.6	$11,362,282

Total tons concentrates.................................1,202,606.9
Total value.................................$59,869,354

[a] *Missouri Bureau of Geology and Mines,* vol. ix, part I.

Since 1905 and up until the close of 1912, the total production of the district has been made by five companies as follows:

Name of Company.	Approximate. Mill Capacity in Tons per 24 Hours.	Approximate. Acreage of Land Owned.
Federal Lead Co..........................	4,500	14,000
St. Joseph Lead Co.[b]......................	3,200	19,000
Doe Run Lead Co.[b]........................	[c]3,000	7,094
St. Louis Smelting & Refining Co..............	2,500	1,300
Desloge Consolidated Lead Co................	1,800	4,400

[b] At the close of 1913 these two companies were consolidated as one company—the St. Joseph Lead Co.

[c] By October, 1913, the Doe Run Lead Co.'s mill will be increased to 4,000 tons per

Flat River, and Leadwood Areas, from 1869 to 1907, inclusive

Compiled from various sources.

Union Lead Co.		Columbia Lead Co.		Leadington Lead Co.		Derby Lead Co.		Irondale Lead Co.		Federal Lead Co.		Central Lead Co.	
Tons Concentrates.	Value.	Tons Concentrates.	Value.	Tons Concentrates.	Value.	Tons Concentrates.	Value.	Tons Concentrates.	Value	Tons Concentrates.	Value.	Tons Concentrates.	Value.
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...	...	...	...	187.5	$5 000	...	...	...	...	...	...	...	...
...	...	...	...	345.5	9,674	...	...	...	...	...	...	350	$9,100
...	...	...	...	Purc	hased b	y . ..	...	...	...	...	...	3,833	82,930
...	...	...	...	Feder	al Lead	Co. ..	...	...	...	...	...	5,470.5	128,060
...	...	...	...	...	...	...	...	...	...	...	...	8,012	192,294
...	...	...	...	...	...	...	...	...	...	...	...	7,931.5	311,311
...	...	...	...	...	...	...	...	...	...	...	...	6,698.3	267,932
35	$1,585	2,701.5	$122,514	...	...	...	...	...	...	...	...	10,655.5	482,694
Pur	chase	d 5,925	207,375	...	...	...	...	...	...	...	...	9,221.0	414,920
by	Doe	5,000	175,000	...	...	531	$22970	790	$27,731	4,32	$161,827	10,553.0	422,100
Ru	n Lea	d 2,700	119,631	...	...	Purc	hased b	y Pur	chased	5,93	310,376	9,574.0	449,978
...	Co.	1,783	79,452	...	...	Feder	al Lead	by Fe	deral	10,40	400,131	6,397.0	307,061
...	...	...	Purcha	sedby	...	...	Co..... ..	Lead	Co.	12,09	604,663	Purch	ased by
...	...	...	Doe Ru	n	...	...	...	...	...	21,27	1,376.624	Federal	Lead Co.
...	...	...	Lead	Co.	...	...	...	...	...	20,21	1,293,572	...	...
35	$1,585	18,112.5	$703,972	533.0	$14,674	534	$22,970	790	$27,731	74,229	$4,147,193	78,695.8	$3,068,390

[a] TABLE II.—*Production Statement for 5-Yr. Period 1908 to 1912, Inclusive*

Year.	Crude Ore Milled. Tons.	Concentrates Produced. Tons.	Average Assay Concentrates Pb. Per Cent.	Metallic Pb. Contents. Tons.	Gross Value.	Yield in Metallic Lead Based on Crued Ore Milled. Pr Ct.	Percentage of Total U. S. Lead Production Thus Represented.
1908	2,747,387	183,095	63.65	116,531	$9,788,604	4.24	37
1909	3,389,742	210,620	60.91	128,299	11,033,714	3.78	36
1910	3,693,523	210,890	62.35	131,499	11,571,912	3.56	35
1911	3,974,712	219,145	67.42	147,754	13,297,860	3.72	36
1912	4,064,366	218,803	67.14	146,913	13,222,170	3.61	35
Totals....	17,869,730	1,042,553	....	670,996	58,914,260	....	....

[a] Compiled from U. S. Geological Survey reports.

Beginning with 1913, production has been started in a small way by a new company in the district, the St. Francois Lead Co., which in 1910 purchased a well situated tract of 357 acres. This ore for the present is being shipped to the mill of the St. Louis Smelting & Refining Co.

Physiography and Geology.

"As a whole the district is rough and hilly, although the only areas that might be called mountainous are in the Southeastern and Southwestern parts in all which occur the Northern spurs of the granite and rhyolite hills and ridges which have been called the St. Francois Mountains. The remaining portion of the area consists of hills and valleys with narrow table land areas and alluvial plains.

"The lowest elevation in the district is 610 feet, along Big River, and the highest 1530 feet at the summit of Middle Mountain."

The accompanying map, Fig. 1, which represents a portion of the U. S. Geological Survey sheets, Bonne Terre and Farmington quadrangles, in 20-ft. contours, shows clearly the surface features of the district, and on this map is drawn a circle of 5-mile radius within which all the disseminated-lead production of the district has been made, other than a few hundred tons from Irondale. Plate I. is a map of the same territory, showing the underground workings.

The Cambrian formation, within the confines of the producing disseminated-lead district, is made up of six members, as follows: [1]

Name.	Thickness, Etc.	Character.
Potosi	Occurs over only a small portion. Normal thickness about 300 ft.	Massive beds of dolomite frequently with cherty nodules and alternating with beds of chert.
Doe Run	Normal thickness about 60 ft.	Shaly dolomite.
Derby	Normal thickness about 40 ft.	Massive dolomite.
Davis	Normal thickness about 170 ft.	Shale and limestone conglomerate
Bonneterre	Normal thickness about 343 ft.	Dolomite, chloritic and shaly near bottom.
La Motte	Normal thickness about 200 ft.	White sandstone.

In general the disseminated-ore horizon occurs in the lower part of the Bonneterre formation, the main bed being usually within less than 50 ft. of the underlying sandstone, with occasional upper layers of ore ranging as far as 300 ft. above the sandstone. The sandstone itself near the top sometimes contains disseminated galena in sufficient amount to permit mining with the limestone, but this ore from the sandstone is relatively unimportant, amounting as it does to less than 1 per cent. of the total.

[1] *Missouri Bureau of Geology and Mines*, vol. ix., Part I.

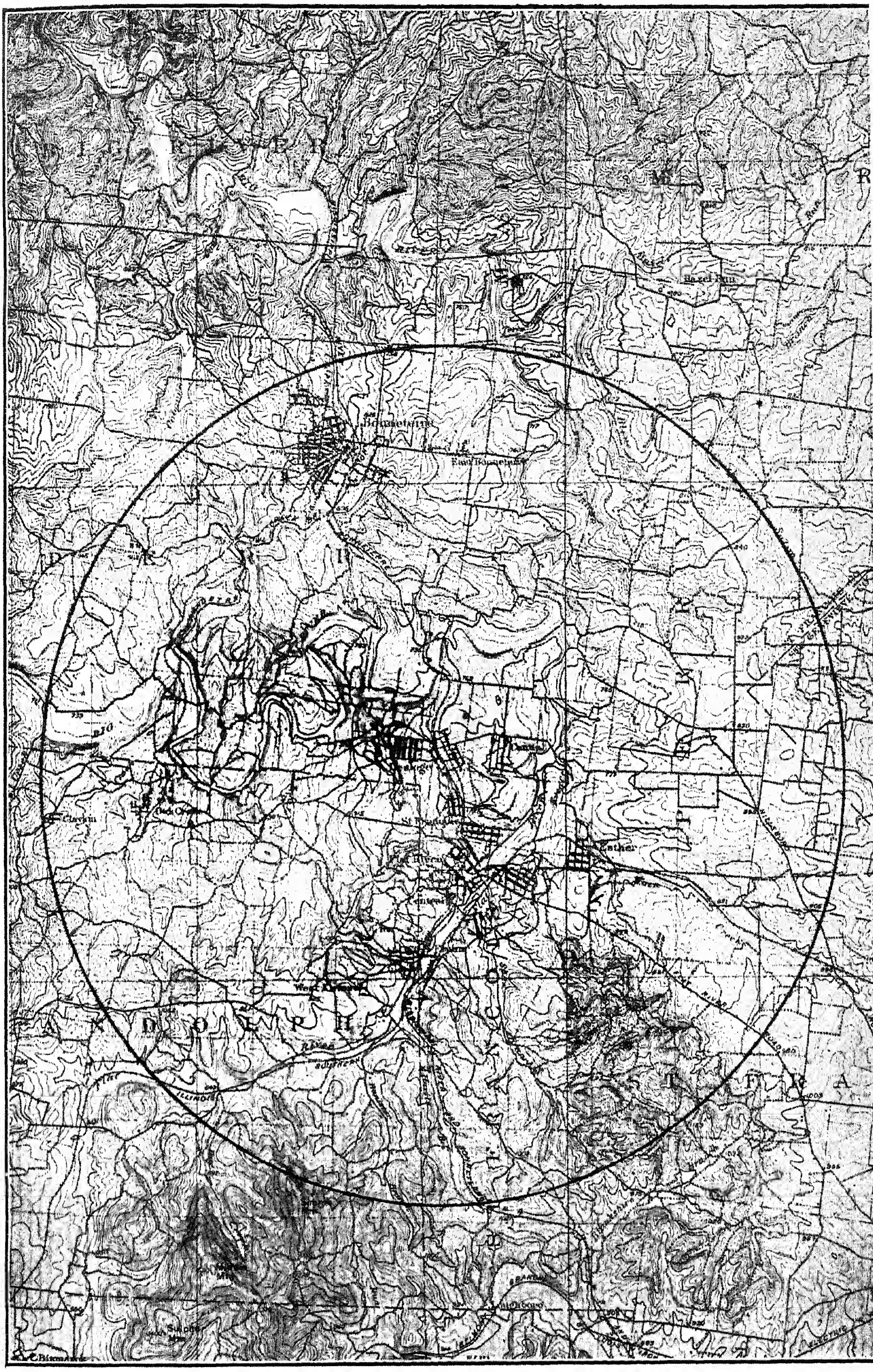
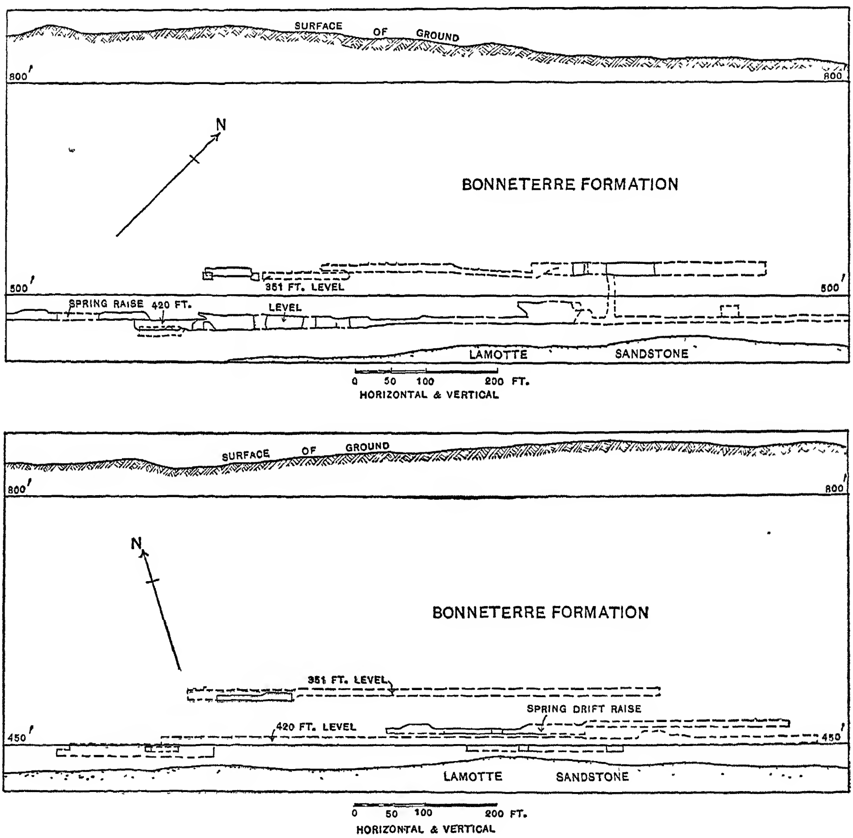


FIG. 1.—CONTOUR MAP OF DISSEMINATED-LEAD DISTRICT.

The accompanying sections, Fig. 2, represent typical occurrences of the disseminated ore in the district where two or more levels are present.

Prospecting

As no outcrops of disseminated ore occur in the district, prospecting, both in the search for new orebodies and for the extension of known ore, is done entirely by drilling, and the formation, other



Missouri Bureau of Geology and Mines, Vol. ix., Ser. 2, Plate LIII.

Fig. 2.—Cross-Sections Showing Position of Orebodies Worked in Federal Mine No. 1, with Respect to the Surface and the Underlying La Motte Sandstone.

than for a little Potosi here and there, is free of flint, so that diamond drilling is used exclusively after reaching solid rock, churn drills being used only for setting the sleeve pipe where the overlying soil or gravel is fairly deep. The district has received great assistance from the Missouri State Bureau of Geology and Mines, by its detailed study of the ore deposits and mapping of the area within

which ore may be expected to occur, but while this is very valuable in a broad way, the fact remains that in extending the limits of known orebodies the only way to do is to feel along with the diamond drill until the full limits of the body are defined. For this work close spacing of holes is used, usually 200 ft., sometimes as close as 100 ft.

For general prospecting in the search for new orebodies the holes are usually spaced 400 or 600 ft. or even further, either in checkerboard fashion or in lines transverse with the supposed strike of the ore run. Then when ore is cut, detailed drilling is begun with spacing of 200 ft. or less. All companies do not follow the same practice in this regard, however.

In drilling, the usual practice is to run with solid bit until within 50 ft. or so of the expected ore horizon and then core until the hole bottoms in La Motte sandstone or—in certain portions of the district—in porphyry or granite. A typical log of a diamond-drill hole where some Davis shale overlies the Bonneterre lime, as taken from Federal Lead Co.'s record, is shown in the accompanying table.

Typical Log of Diamond-Drill Hole

Number 2561.

Location: Tract No. 7. N. 673.84. E 1419.26.

Sleeve 839.81.
Bonne Terre Dolomite 776 81.
La Motte Sandstone 389.81.

Date 5/19-5/31. 1913.

Description by ______________

Core Saved.	Depth.	Thickness.	Description.	Elevation A. T.	Thickness of Ore.	Estimated Lead Per Cent.		Accepted Per Cent.
	3		Sleeve					
	63		Shale.	776.81				
	340		Light lime					
	350		Gray lime					
			Began Coring.					
1 ft. 0 in.	351		Dark gray lime, traces lead	488.81	1.0		traces	
	365		Dark gray lime, lead at 354-356-358-361-364					
9 ft. 5 in.	375		Gray lime, traces lead	464.81	10.0		traces	
2 ft. 0 in.	377		Gray lime, traces lead.	462.81	2.0		traces	
6 ft. 6 in.	384		Siliceous shale; gray lime; traces lead sulphur	455.81	7.0		traces	
3 ft. 6 in.	387.5		Siliceous shaly gray lime.	452.31	3 5	2.0		
10 ft. 3 in.	398		Gray shaly lime	441.81	10.5	3.0	3 3	
1 ft. 11 in.	400		Gray shaly lime	439.81	2.0	7.0		
9 ft. 8 in.	410		Siliceous chloritic gray lime	429.81	10.0	1.0		
4 ft. 0 in.	414		Siliceous shaly gray lime; traces lead.	425.81	4.0		traces	
	420		Gray shaly lime					
1 ft. 6 in.	421.5		Chloritic gray shaly lime; traces lead.	418.31	1.5		traces	
	423		Gray shaly lime					
8 ft. 11 in.	432		Siliceous sandy gray lime	407.81	9.0			
1 ft. 11 in.	435		Siliceous sandy gray lime; traces lead.	404.81	3.0		traces	
7 ft. 0 in.	442		Siliceous sandy gray lime; traces lead	397.8	7.0		traces	
3 ft. 7 in.	446		Siliceous shaly gray lime; traces lead.	393.81	4 0		traces	
	450		Gray sandy lime; traces lead at 449	389.81				
	460		Clear white sand	379.81				
			Bottomed at 460.0.					
			Water returned.					
			Pay					

The mineral run of the drill core is not as a rule assayed, except from time to time as a check on the estimations, but instead of this the mineral run is filed in a core tray, suitably labeled, its metallic lead contents carefully estimated, and the tray filed in the corehouse for future reference. Where a dozen or more drills are being operated by a company, a trained estimator is kept steadily engaged upon this work.

The costs per foot for diamond drilling in the district depend upon the distance for haulage of fuel, facilities for water, the contour of

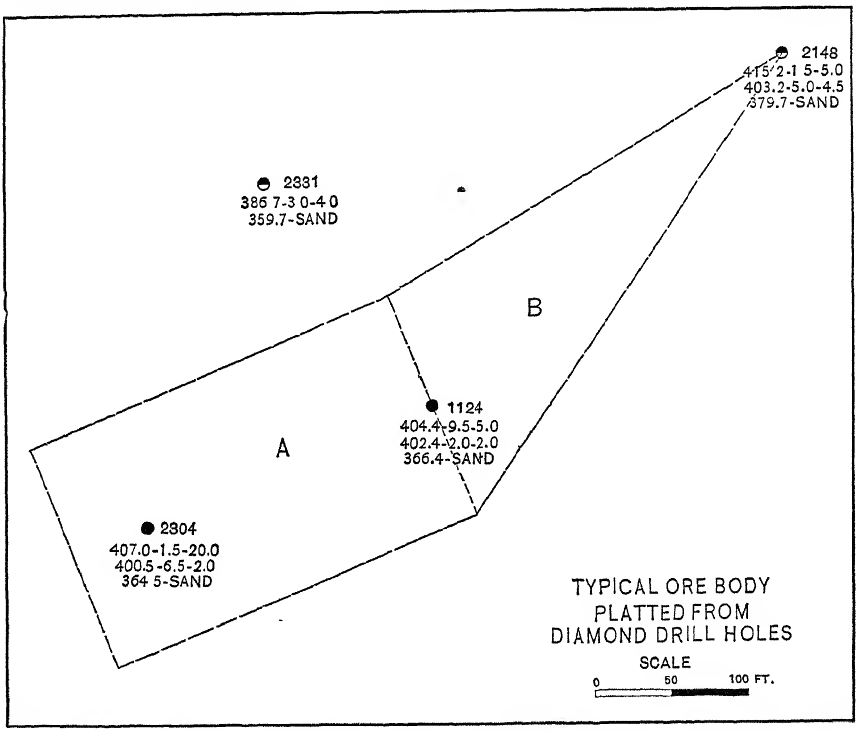


FIG. 3.—MAP OF OREBODY PLOTTED FROM DIAMOND-DRILL HOLES.

the ground, the rock formation, the depth of hole, the proportion of solid-bit to core-bit work, and the amount of time and care spent upon the collecting, estimating and storing of the cores, and it varies accordingly from 60 c. to $1 per foot with an average of say 75 c., made up about as follows:

Labor	$0.25
Carbons	0.25
Fuel, etc., and haulage	0.10
Repairs and renewals	0.15
	$0.75

In point of footage per 10-hr. shift solid-bit work will average say 60 ft. and core bit 30 ft. Approximately 25 per cent. of the total footage is cored. Careful attention is, in general, given by the companies to plotting upon their maps the drill holes and their records of ore, and calculating therefrom the probable orebody in terms of tonnage, thickness and grade. Experience has shown that in general the estimates thus made are fully borne out when it comes to actual working underground, so that ore reserves thus calculated can be safely relied upon.

The subjoined portion of a 50-ft. scale map, Fig. 3, shows a typical area in which drilling has yielded a number of pay holes and the orebody shown has been plotted as a result.

This will serve to illustrate the method of calculating tonnage, thickness and grade, as used by one of the larger companies of the district—the Federal Lead Co.—as follows:

Portion A, area : 250 by 150 ft. =	37,500
Portion B, area : 352 by 66 ft. =	23,232
Total area............................	60,732

In calculating thickness and grade of the orebody, each hole is first considered separately and then all are combined to obtain an average, thus:

Hole.	Elevation.	Thickness. Ft.	Pb. Per Cent.	Ft-Per Cent.
2,304	407.0	1.5	20.0	30.0
....	400.5	6.5	2.0	13.0
Totals and average........		8.0	5.4	43.0
1,124	404.4	9.5	5.0	47.5
....	402.4	2.0	2.0	4.0
Totals and averages......		11.5	4.5	51.5
2,148	403.2	5.0	4.5	22.5
Total and average........		5.0	4.5	22.5

To find the average thickness and grade of the entire orebody, all holes within the limits of the body are considered. In this particular case the body was cornered at 2148 as the ore in this hole is scarcely a pay run.

Hole.	Elevation.	Average Thickness. Ft.	Average Per Cent. Pb.	Ft-Per Cent.
2,304	400.5–408.5	8.0	5.4	43.2
1,124	402.4–413.9	11.5	4.5	51.8
2,148	403.2–408.2	5.0	4.5	22.5
Totals and average........		24.5	4.8	117.5
Average thickness and grade.........		8.2	4.8	

Calculations for tonnage are given below, using 11 cu. ft. per ton and figuring only 50 per cent. of the volume as ore, the rest being considered poor ground and pillars.

Thickness. Ft.	Grade of Ore Per Cent	Area of Body. Sq. Ft.	Volume of Body. Cu. Ft.	Volume of Ore. Cu Ft. = 50 Per Cent. of Vol. of Body.	Tons Ore. 11 Cu. Ft. to Ton.	Tons Pb.	Elevation of Body.
8.2	4.8	60,732	498,002	249,001	22,637	1,087	400.5–413.9

Mining

Location of Shafts and Hoisting

Shafts are preferably located centrally to the tributary orebodies, and should be at a point where the sandstone—which is the limiting lower horizon of the ore—is lowest, so that a skip pocket may be cut —if skips are used—and a pumping sump arranged at a level low enough to bring both ore and water to it on a down grade.

In earlier days the hoisting was by cages and cars, but the use of skips is becoming more general, the usual practice for this being double skips of 5 tons capacity with loading pocket of 100 tons or more and loading gates operated with compressed air. Pockets are usually lined with steel rails.

Of the 21 shafts now operating in the district, 17 use cages and cars, and four use skips; 12 use electric hoisting and the rest steam. Average rope speeds during hoisting are in the former case 800 to 1,000 ft. per minute for cages and 500 to 550 ft. per minute for skips, while with steam they are 960 to 1,200 ft. for cages and 500 to 800 ft. for skips.

Ore Breaking

Stopes are carried for the full height of the orebody and the broken ore is shoveled from the flat bottom into cars. Where the ore is not thicker than 8 ft. the stope is carried by breast holes from drills mounted on columns. If top and bottom of the stope both present good bedding planes to break to, the stope can be carried with two holes up to a 7 ft. height, otherwise three holes will be required. Where three holes are used the top and bottom holes are in the same vertical plane and the middle hole is set forward 6 in. nearer the face to be broken. The top hole looks up a little, the middle hole looks down just enough to hold water, and the bottom hole also looks down a little.

All the holes are carried approximately parallel with the face. In starting off such a stope, say as in turning around a pillar, three short—4 to 6 ft. length—holes are drilled as a cut to start the stope. The average length of regular breast hole is 7 to 7.5 ft. For stopes

too high to break from a column, the upper part is carried forward by breast holes precisely as in regular column-high ground, and the lower portion or stope is broken by vertical holes, the bottom being trimmed by lifters. Where the portion below the breast is only say 10 ft. thick it will be broken by one series of vertical holes of 7 to 7.5 ft. depth and the remaining 3-ft. layer taken up cleanly by flat holes or lifters. These flat holes ordinarily look down only sufficient to hold water and are drilled usually to 10 ft. length.

This same procedure is followed up to a maximum thickness of say 14 ft. for this portion below the breast, unless the floor is good to break to, in which case very few lifters are used and the 14 ft. is broken in two successive layers, by vertical holes. This same method of carrying forward the breast and then breaking the lower or stope portion by breaking in layers with vertical holes is used up to the extreme heights of stopes, which sometimes run to 70 ft.

In regard to spacing for holes and the burden to be carried, where column-high ground is being carried by two breast holes, the burden is usually 3 ft.; where three holes are used the two back holes carry 4 ft. of burden and the middle 3.5 ft. For stope holes except close to pillars the spacing is approximately 8-ft. centers and the burden 5 ft.

In loading these holes, for breast work, the two rear holes usually take 12 0.5-lb. sticks of 35 or 40 per cent., $1\frac{1}{8}$-in. powder, either nitroglycerine or gelatine. The middle hole is loaded with about 14 sticks or 7 lb. and is fired first. In stope holes, where, as is often the case, three holes are drilled in a row between pillars, the two end holes are each charged with about 12 sticks of powder and the middle with 18, and the middle hole fired first. The charge for the lifters varies but in general is much lighter per foot, as the burden is less both in point of measurement and because of its shattered condition.

In driving the breast, care is exercised in pointing the upper holes, to avoid breaking into and burning the roof or back. Loose or drummy portions of the back are taken down by flat gads or moils, using black powder whenever it is necessary to shoot any of these portions.

In point of danger from roof falls, the experience is that tight limestone is the safest and most dependable roof, while shaly backs are the most dangerous, frequently coming down without warning, especially if they show water seepage. Such roofs require pillars at frequent spacing. Also it is often necessary to take down the roof in a manner so as to arch it between pillars. For average ground, however, pillars are spaced about 30 ft. between circumferences and are of 18 ft. average diameter, representing approximately 15 per cent. by volume of the total ground mined.

In turning pillars the holes are placed so as to shoot away from the pillar and avoid danger of shattering.

Where more than one level is worked, care is used to insure that wherever levels, which are close together, overlap, their pillars will

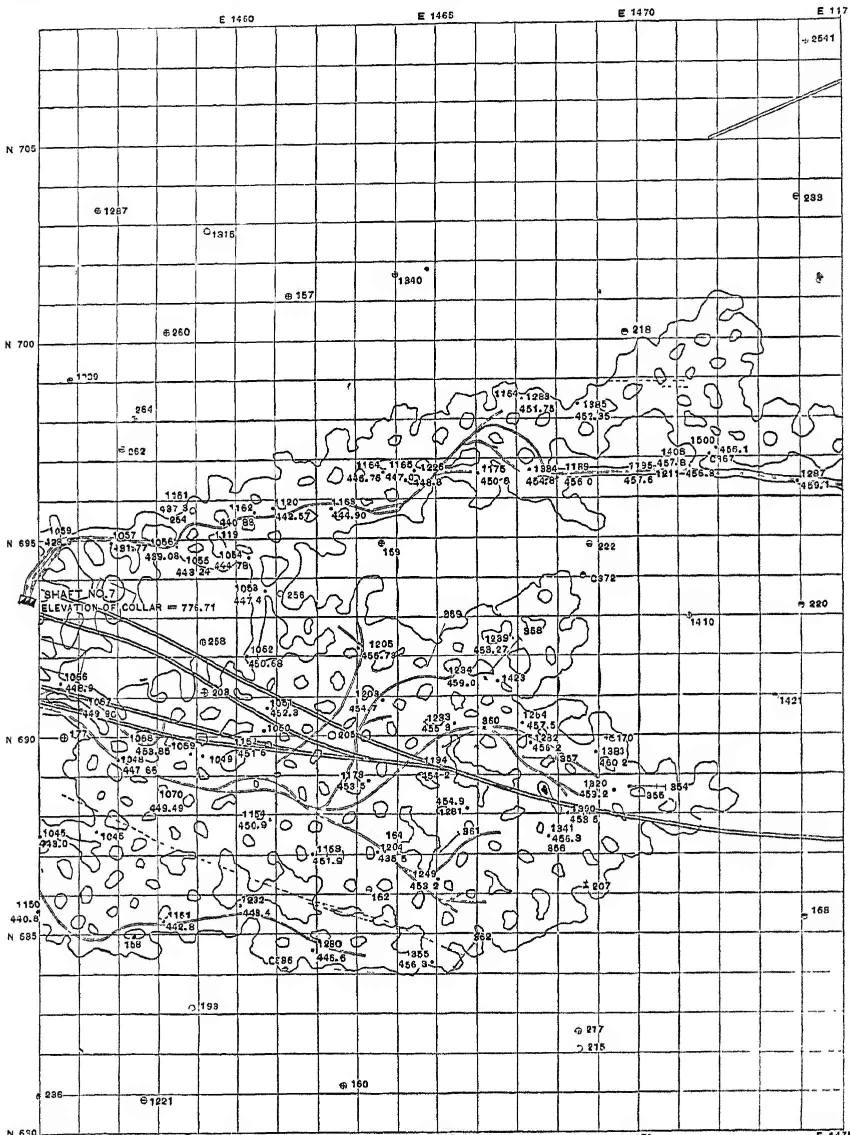


Fig. 4.—Map of a Portion of a Typical One-Level Mine.

be properly centered, the upper over the lower. The map, Fig. 4, represents a portion of a typical one-level mine in which the stopes vary from 7 to 40 ft. in height.

Powder.

The bulk of the powder used is 40 per cent. gelatine or nitroglycerine with some 35 per cent. gelatine; No. 6 caps and rubber- or gutta percha-covered fuse are used.

Drills.

Less than 5 per cent. of the drills of the district are now run with two men, and it is probable that within another year nothing but one-man drills will be in use. The type first adopted by those companies who changed from two-man to one-man drills was the Sullivan U. S. 2.25-in., and there are still more of those drills than of any other in use in the district. Within the past year, however, faster cutting drills than even the 2.25-in. Sullivan have been sought, and as a result one company has adopted water Leyners throughout, while two other companies are using the Ingersoll C-110 2.75-in. butterfly-valve drill for a large part of their work. Attention has also been given of late to the large amount of time consumed particularly in tripod work in setting up, even with the one-man drill, and several of the companies are therefore beginning now to use hammer drills of the self-rotating type for down holes and even for lifters. These hammer drills for holes of not over 8 ft. depth will drill fully as fast as piston drills and no time is consumed in setting up, while the air consumption is only about one-half that of a 2.75-in piston drill.

Steel is 1-in. octagon, solid, except for the Leyners, while for the hammer drills $\frac{7}{8}$-in. hollow steel is used. The sets are of 2 ft. range from 2 to 12 ft. for piston drills and 2 to 10 ft. for hammer drills. Machine sharpening is quite general throughout the district, using either the "Z" bit or the + bit, and for the hammers a 6-star bit.

Up to 1908 the ore was either broken by day's pay or else by contract at so much per linear foot of hole drilled. This latter system did not prove satisfactory, however, as great care was necessary to insure accurate measurement of the holes, and it was also found that the proper tonnage per foot of hole was not being obtained, the tendency, even with close supervision, being to locate holes more with reference to ease in setting up than to tonnage they would break.

In the fall of 1908 the system was introduced by the Federal Lead Co. of letting small contracts of two or more stopes to suitable men at so much per ton for breaking. This system compared to day's pay has some drawbacks in that it is not as flexible in the way of shifting the work from place to place without notice. Also it takes some care to keep proper records of the tonnage pulled for each contract,

but on the other hand it has built up an excellent group of machine men in the district, who, whether as contractors or as employees of these contractors, are, by skill in placing holes and by close attention to their work, able to earn on an average say 15 to 20 per cent. more than the prevailing company wage of $2.75 for underground drilling, and to do this at a contract cost per ton that is fully as low as could be obtained by company day's pay operations at the prevailing wage.

That the system has upon the whole proved satisfactory both to the companies and the machine men is seen from the fact that over 80 per cent. of the tonnage of the district is now broken by per-ton contract, at a cost for labor of about 11 c. per ton, and an average earning—figuring the shifts of labor into the amount paid—of close to $3.25 per man per shift. A large item of labor expense in connection with ore breaking is that of roof miners to take down all loose rock and keep the backs safe. This is taken care of by day's pay. Adding this cost to the 11 c. makes a total of approximately 14 c. as total drilling labor cost per ton.

Consumption of air and of powder has also been lessened by the contract system, as more skill is used in placing holes and therefore more tonnage broken per linear foot of hole. Approximately 29 ft. of holes are drilled per shift per single machine and approximately 1 ton is broken per foot of hole.

Power costs, as compressed air for drilling, are approximately 5 c. per ton and explosives 8 c. Air is distributed to the drills at about 80 lb. pressure.

Stopes are wherever possible arranged so that if the ore bed has a little dip, the stope approaches it from the lower side and works uphill, so as to ease the ore haulage and keep the faces or headings free of water without the use of heading pumps, which, operating as they must, on compressed air, are expensive. Tracks are all 24-in. gauge and 25-lb. steel is the usual weight. Ties are of oak 4 by 6 in. by 4 ft. and are spaced 2-ft. centers.

Development Work

Drifts are cut 7 ft. high by 8 ft. wide, and while the center-cut method of breaking is sometimes used it is chiefly for extra wide or 10-ft. drifts for double track, and in general the side-cut method is used. In this method, 12 holes are usually used. This will square 3.5 to 4 ft. These 12 holes are made up thus:

First.—Four holes in a vertical row for the cut with a depth of 4 to 6 ft., collared about 3 ft. from the side of the drift and looking so as to meet the side line at their bottoms.

Second.—Three holes in a vertical row, collared 18 in. behind the cut row. These look less sharply, so their bottoms are 30 in. from the side wall. These average 7 ft. in depth so as to gain ground in going across the drift.

Third.—Three holes in a vertical row close to the far wall of the drift and looking parallel therewith, having a depth of 8 to 10 ft. Then in front of these three holes and spaced between top and middle and between bottom and middle are two relief holes of same depth, but looking a little toward the cut side.

In case of hard-breaking ground 16 holes are sometimes necessary, made up in that case of four vertical rows of four holes each. The different vertical rows are fired in series from cut side to square-up side. This gives a beveled square-up or face to the drift and the next slice is taken by reversing and putting the cut holes on the opposite side.

Raises are nearly all put up on a 45° to 50° slope following the same breaking method as in drifts, usually taking 16 holes in the raise. These raises are put up 7 by 10 ft. and a manway is then partitioned off at one end by cutting hitches and putting in 8- by 8-in. stulls every 6 ft., lining this with 2-in. oak. The manway is provided with a ladder or preferably a stairway and the end is closed with entrance at the side, thus avoiding danger to the loaders below from rocks falling down the manway. The gate at the bottom of the chute is usually of sector type operated with crank arm over which is placed a 2.5-in. pipe for leverage.

Shoveling and Tramming.

All ore in the district is shoveled off a flat bottom into cars, which are trammed to raises and dumped, if on an upper level, or to the shaft if upon the main level.

Up until the end of 1912 nothing but hand work had ever been used for shoveling, but in January of this year the Federal Lead Co. introduced mechanical loading in a trial way at one of its mines and since that time has been shoveling with this mechanical shoveler about 7,000 tons per month, working two shifts per day. This machine is the No. 4 Myers-Whaley shovel made in Knoxville, Tenn., and was first described at length in *Engineering News*, Sept. 5, 1912. In this machine there are two distinct operations for loading and conveying. The loading element has a forward shoveling or thrusting movement actuated by a rotating crank and as the crank moves further it lifts the shovel through the material until the shovelful slides down into the inner or rear shovel. As the crank continues to

rotate the rear shovel is forced backward and up the inclined camway until finally at the end of the stroke the material is discharged upon the belt conveyor and thence to the car. The shoveling action is continuous and automatic.

The accompanying photographic view, Fig. 5, gives a general idea of the machine as at work. It is improbable that it will ever be found profitable to use this mechanical shovel except in stopes 20 ft. or more in height, as in the lower stopes the small size of the piles of broken rock would render necessary the frequent moving of the shovel. In high stopes, however, especially 40 ft. or higher, where the broken piles are large, the shovel is likely to find extended appli-

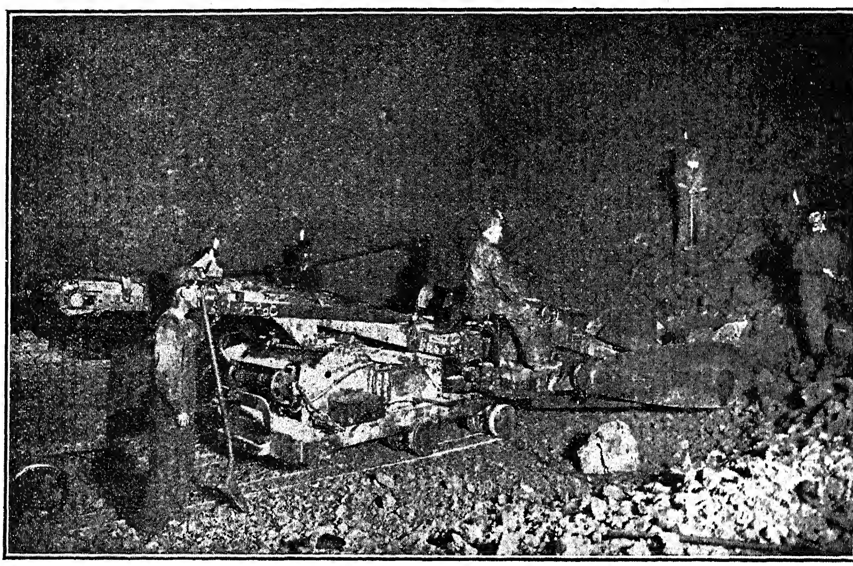


FIG. 5.—MYERS-WHALEY NO. 4 MECHANICAL SHOVEL AT WORK, FEDERAL LEAD CO.'S SHAFT NO. 11.

cation in this district, and although it is doubtful if it will on an average give a per ton shoveling cost any lower than hand shoveling, it will be especially useful in times of labor shortage or when an increase in production is desired.

The tonnage shoveled per man for hand shoveling depends upon the supply of rock and the condition of the floor; it averages for the district about 18 tons per man. Long-handled, round-pointed No. 2 shovels are used requiring about 130 shovelfuls to fill a 1-ton car or 15 lb. per shovel. The cost per ton for shoveling averages 13 c.

Ore cars of the district are in general 1-ton cars of rectangular shape with flat or round bottoms. They are dumped at the top land-

ing by tipple, being pushed by hand either into the tipple or, as in case of Desloge, by air- or steam-operated piston, with a suitable hook at the end of the piston to hold the car and return it to the cage. Self-dumping cages of the type frequently seen in coal fields are used at one or two shafts in the district.

The power-dumped cars are usually a little larger than those for hand tipple dump, being of 1.5 to 1.75 tons capacity. Cars of "A" dump model of 1.4 tons capacity are used at the Federal for dumping into pockets for skip hoisting.

Cages, where used, go to solid landing at bottom and rest upon chairs at top landing, the latter being pushed in and out by lever.

In the matter of car wheels and bolsters, the styles are not uniform throughout the district but the practice at the Federal may be taken as fairly typical. Two types are there used:

First.—Roller-bearing bolsters with cast-iron wheels sufficiently open at the spokes to permit spragging on down grades by inserting a 2-ft. length of 1.25-in. pipe. These run with little friction and in that respect are the most satisfactory. Further, once packed with cup grease they require no more attention for oiling for three months or more. For miscellaneous work, however, where the grades are frequently over 3 per cent. these cast-iron wheels are liable to break by spragging under loaded train, and for such ground the second type is used.

Second.—Cast-iron bolsters, which are bored out to fit 2-in. axles but are not babbitted, and manganese-steel wheels with axle put on by hydraulic pressure. The axle is held in place in these bolsters by a fork and the bolster has a sump or oil cellar from which oil flows to each axle, using Summer black oil.

Mules are in general used only in gathering cars from the headings, while for haulage to the shaft, particularly where the distance is great, power haulage is used. At the Federal and St. Louis Smelting & Refining Co. (National) electric haulage is used exclusively; 250-volt direct-current locomotives, mostly 6-ton size, are used, and are run either single or double header according to the train load. At the St. Joseph and Doe Run, Porter high-pressure air locomotives are used, varying in size from 4 to 9.5 tons weight. Some gasoline locomotives are also in commission. At Desloge gasoline locomotives are used exclusively for power haulage underground, the Desloge being the first to adopt gasoline haulage in the district.

Tramming costs, underground, for gathering with mules and haulage to shaft, average about 5 c. per ton exclusive of track work.

Lighting

Lighting underground at stations and along drifts is by electric incandescent lamps. For individual lights for the men "sunshine" is used exclusively. About three years ago an economy in the use of this material was introduced by the Federal company, which arranged with the manufacturers to mold this into briquettes of a size to last 8 hr., thus avoiding the waste incident to dealing this out in bulk. The size is usually one brick of 12 oz. for shovelers and machine men and 1.5 bricks to drivers, and hand miners who do more traveling.

Drainage

The amount of water pumped from the mines is greater in the spring, but the year's average for the district[2] is about 12,500 gal. per minute under an average friction and static head of 500 ft. The tendency for pumping as for other large power requirements is to centralize power generation and distribute power electrically, but progress in this respect has not gone as far in the case of mine pumping, so that at the present time the bulk of the water, that is to say approximately 8,000 gal. per minute, is still handled by steam pumps, while 3,000 gal. per minute is pumped by motor-driven centrifugals, usually five stage,[3] and 1,500 gal. per minute by motor-driven geared plunger pumps, triplex or quadruplex. Most of the steam pumps are duplex tandem-compound with jet condensers, with one or two fly-wheel pumps, the latter being naturally more efficient. On the whole, however, the steam pumping will not show an efficiency over 45 per cent. carried back to the boiler.

The centrifugal pumps will average about 55 per cent. efficiency, similarly considered, and the geared plunger pumps not over 75 per cent., so that the pumping for the district as a whole shows about 50 per cent. efficiency carried back to the boiler. This figures a power consumption operating continuously of approximately 3,200 h-p. or about 7 h.p-hr. per ton of ore on the 1912 production, making a drainage cost for the district of about 8 c. per ton including labor, supplies, and repairs.

Power

Considerable progress has been made during the past few years by the operating companies in the way of centralizing power generation.

The St. Joseph and Doe Run each have central power plants with

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[2] Compiled from information given by the managers of the different operating companies.

[3] By April, 1914, approximately 2,500 gal. per minute now pumped by steam will be handled by motor-driven geared triplex or quadruplex plunger pumps.

Loomis-Pettibone and Westinghouse gas producers, and double-acting twin-tandem Snow horizontal gas engines direct connected to 6,600-volt, three-phase, 50-cycle generators, and distribution is made at that voltage. In addition, the St. Joseph has steam turbines both high pressure and mixed pressure, and Corliss compound, condensing reciprocating engines.

The Federal has one central power plant using chain grate stokers and Curtis turbines, current being distributed at 2,200 volts, three phase, 60 cycles; also some auxiliary steam plants for pumping, air compressing, and hoisting.

The National central power plant uses underfeed stokers, reciprocating engines, direct-current generators, and distributes at 500 volts.

The Desloge uses chain stokers and reciprocating engines direct connected to the mill.

Coal comes from various points in Illinois, costing on mine run base 90 c. to $1.10 f.o.b. mines with freight rates from 70 to 90 c. per ton.

Total power consumption[4] for the district averages about 10,000,000 h.p-hr. per month, and figuring this in horsepower-hours per ton of ore mined and milled gives 30 hr., the distribution being about as follows:

Air compressing	6.5
Drainage	7.0
Underground haulage	0.8
Hoisting	1.2
Crushing and milling	13.0
Lighting	1.0
Heating and miscellaneous	0.5
Total	30.0

In the matter of coarse crushing, the St. Joseph, Doe Run, and Desloge crush to about 4-in. size, with gyratories at each shaft, before hauling to mill, while at Federal and National all crushing both coarse and fine is done at the mill.

Surface transportation from shafts to mills is done by standard-gauge steam railroads. The Federal, Desloge, and National each have a railroad of their own for haulage service only, while the St. Joseph and Doe Run control a railroad of about 60 miles length which, in addition to ore service, does a general freight and passenger business.

[4] Compiled from information given by the managers of the different operating companies.

Acreage Mined.

Approximately 540 acres of ground, excluding pillars, has been stoped since the commencement of mining in the district, of which about 285 acres was mined from 1869 to 1907, and about 255 acres from 1908 to 1912, inclusive. During the past few years the number of tons of crude ore per acre mined has averaged for the district about 75,000.[5]

Mining Costs, Tons per Man, Etc.

Costs per ton for crude ore mined and delivered to mill bins average about 85 c. for the district, exclusive of diamond drilling and other prospecting, which is variable with the different companies and may range from 5 to 15 c. per ton.

Tons per man for all underground labor averages about 5.7, distributed about as follows:

Classification.	Tons per Man.
Superintendent, foremen and bosses	195
Stablemen	650
Mule drivers	55
Motormen	500
Gatemen and chute tenders	400
Spraggers and car dumpers	400
Blacksmiths and helpers	500
Trackmen	100
Hand miners (for safety of roofs)	90
Blasters	800
Cagers and landers	180
Watchmen, car cleaners and yardmen	250
Machine-drill men	29
Shovelers	18
Miscellaneous	200
Average for total underground labor	5.7

The crude-ore output as tons per man for all employees of the five operating companies, for prospecting, mining, and milling was 2.96 for the year 1911;[6] for 1912 the State report will doubtless show a little higher, due largely to progress in the way of centralizing operations, particularly power generation, milling, and hoisting.

[5] Compiled from information given by the managers of the different operating companies.

[6] According to the *Twenty-fifth Annual Report of the Missouri Bureau of Mines.*

Discussion

William Whaley,* Knoxville, Tenn.—Reference is made in Mr. Guess's paper to the Myers-Whaley Co. shoveling machine, and the opinion is expressed that "it is improbable that it will ever be found profitable to use this mechanical shovel except in stopes 20 ft. or more in height, as in the lower stopes the small size of the piles of broken rock would render necessary the frequent moving of the shovel." It is also stated that it is doubtful if average per ton cost of shoveling is any lower than by hand.

I think that further data should be given, as I do not agree with either of Mr. Guess's conclusions above. The shoveling machine is very portable and moves under its own power from one place to another in a few minutes, usually between 5 and 10 min., and to get profitable operation in low mines it is only necessary to provide more places for the machine. If there are enough working places averaging, say, only 20 tons per place within a distance of 600 ft. of each other to make an output of 150 tons per shift, the operation is profitable. For instance, a 20-ton place would be loaded out in half an hour, and moving to a second place 600 ft. distant would consume 15 min., or a place and a move in 45 min. Assuming a loss of 2 hr. per day from incidental causes, car delay, track, etc., the number of places worked per day would be eight, or 160 tons. The machine is run by one man, two men shift the cars, and a fourth cleans up and helps generally; total labor cost is $9.80, or 6.1c. per ton, which certainly should show a reasonable profit compared with 13c. per ton by hand.

The tracks should be solid and well supported and the cost per ton of laying track is more in low stopes than in higher, increasing in inverse ratio to height of stope, but that is the only item of cost which is increased with moderately low workings. This track cost increases for hand shoveling as well as for machine shoveling. At the Flat River mines, the gauge of track is 24 in. It is necessary to use outside rails for the machine at the working face, making four rails for each track for a distance back of about 30 ft. If wider gauge track were used the cost of track laying for the machine would be materially reduced, and a marked increase in efficiency would follow. In coal, iron-ore, and rock-salt mines it is usual to find track gauges of 36 to 44 in. In these mines it is easier to get a solid track, for the ties are not so high above the solid bottom as is the case in the Flat River mines.

The cost of track laying at Flat River is possibly such as to make the use of machines unprofitable to the Federal Lead Co. in stopes less than 20 ft. high, as the company pays a contract price for the material loaded by machine, which price was intended to nearly approach hand cost.

* Non-member.

The machine at Federal is operated by a contracting company which owns the machine and loads ore at a price of 10c. per ton for the machine and one operator per shift. This company is making a profit of $250 to $300 per month above cost of upkeep and operation, despite the fact that the cost of operation is high because the company's headquarters is several hundred miles away and it is necessary to have a high-priced man in charge of the machine, one who is competent to attend to any repairs that may be needed. It costs the contracting company $9 per two-shift day for operators, whereas if the machine were owned by the mining company the operators would be paid about $2.75 each, or $5.50 per day of two shifts, the mine master mechanic then carrying the responsibility of mechanical attention.

As an example of the use of machine in comparatively low headroom, I give some data of a machine at work in the rock-salt mines at Retsof, N. Y. This seam is 8 ft. thick, and the machine has averaged a loading of 250 to 300 tons per shift (about twice the output at Flat River). The cost is about 4½c. per ton. This tonnage is only possible where a large quantity of material can be shot down, which of course is very much simpler in coal or salt than in rock. The upkeep of the machine at Retsof is 0.7c. per ton of salt loaded. The mining conditions are as follows:

Width of working places, 30 ft. Thickness of seam, minimum, 5 ft.; maximum, 10 ft.; average, 8 ft. No impurities. Track gauge, 36 in. Roof, salt and shale. Working places dry. No timber is used. Drilling is done with rotary electric drills. Power, 250 volts, D. C. Salt is shot loose in fine and blocks. Cars hold about 3½ tons.

The points to be noted are that, generally speaking, the machines are applicable to comparatively low mine workings, and can be profitably employed wherever sufficient tonnage can be shot loose, either in big piles or in a number of smaller piles in adjacent territory.

Drilling Performances at the Kensico Dam, Catskill Aqueduct System, New York

BY W. L. SAUNDERS, NEW YORK, N. Y.

(New York Meeting, February, 1914)

General Description of the Work

WHEN work was begun in September, 1910, on the rock excavation for the foundation of the gigantic dam at Valhalla, N. Y., which is to convert Kensico lake into an important storage reservoir of the Catskill Aqueduct

FIG. 1.—SITE OF THE NEW KENSICO DAM.
Part of the old Kensico Dam at Extreme Left.

system, one of the first steps taken by the contractor, H. S. Kerbaugh, Inc., was the development of a quarry to supply the stone needed in the

construction work. The importance of a bountiful supply of suitable rock in an accessible location is apparent when it is considered that nearly a million cubic yards of cyclopean masonry will be contained in the completed structure, not to mention dimension and facing stones, concrete blocks, and mass concrete.

The dam structure will be over 1,800 ft. long and about 170 ft. above the present river bed. However, for a distance of some 800 ft., it will be carried down to solid ledge rock, which will make the finished structure about 300 ft. in maximum height. It will be about 200 ft. thick at the base and directly beneath the coping it will be 28 ft. thick.

This dam will raise the reservoir surface 110 ft. above old Kensico lake. The reservoir capacity will be 29,000,000,000 gal.—equal to New York's total needs for over two months.

The contract price for this work is nearly $8,000,000 and is second only in amount to the cost, over $12,600,000, of the Ashokan Reservoir work. Fig. 1 is a view of the dam site

The Quarry

The quarry site is about a half mile away from the dam. The rock is a clean and practically flawless gneiss having a tendency toward granite. In some places, however, it is seamy, presenting more or less difficulty to drilling, but in the main it is hard and solid. The rock surface is fairly level, affording a good footing for the drilling apparatus.

Thirty tripod drills and four drill wagons, all of the electric-air type, were purchased for this work, but the drilling has progressed so rapidly that enough holes have been put in to supply rock for a year or two, consequently most of the drills and operators have been laid off and only a few tripod drills and the four drill wagons are in operation at the present time.

Tracks run from the quarry directly to the dam site; a main line with several branches has been cut into the various parts of the quarry. The drills are mounted on the high rock adjacent to these cuts and put in rows of holes parallel with the tracks, all bottoming at a common level. After the holes are drilled to depth, wooden plugs are inserted to keep dirt from entering them. (See Fig. 2.) A great number of holes are shot simultaneously, loosening up a large area of rock at a single blast, as shown in Fig. 3. The rock is removed and placed on flat cars by 90-ton steam shovels, which advance along the track after the blast.

Stone of suitable size is removed bodily and imbedded in the concrete at the base of the dam and in the dam structure. The remaining rock is conveyed to a large rock-crushing plant located adjacent to the quarry, where it first goes through a gigantic jaw crusher, then through smaller crushers, is screened, falls by gravity into dump cars and is transported

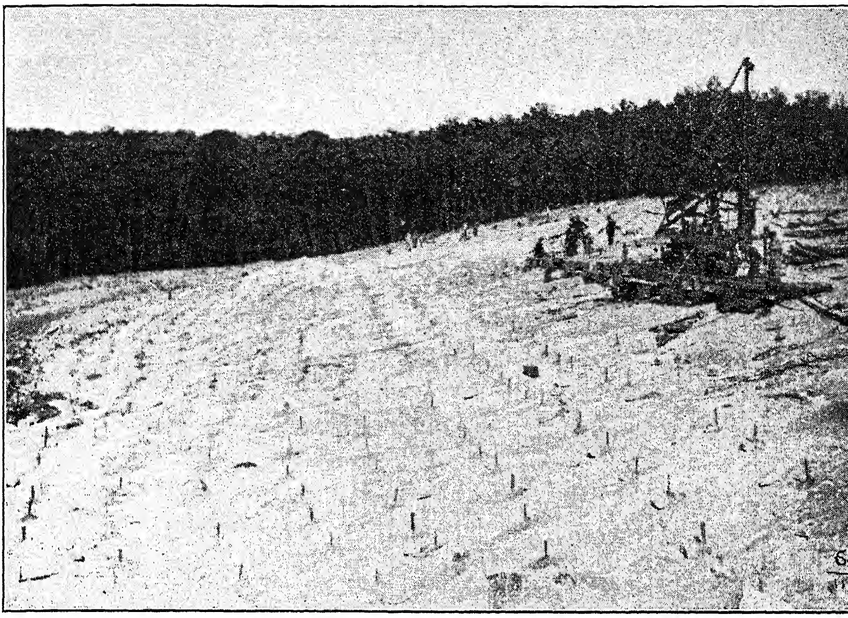

Fig. 2.—A Battery of Holes in the Quarry Ready for Blasting.

Fig. 3.—After a Blast at the Quarry.

to the dam. The large jaw crusher was designed to crush exceptionally large stones, thus avoiding considerable labor incident to pop-shooting.

Power

Electric power operates all of the apparatus at both dam and quarry, excepting the locomotives and steam shovels. The transmission line for the three-phase, 60-cycle, 66,000-volt alternating current extends about 4 miles, from Yonkers to a sub-station near the reservoir site, following the Aqueduct right-of-way. The sub-station contains six transformers which reduce the voltage to 2,200. Pole-type transformers of either 488 or 244 volts are employed for stepping down the current for the machines. The wires are carried along the ground to the individual drilling machines.

Locomotives and cars are used mainly for conveying the material. Traveling cranes, operating on parallel tracks, place the building material. Each traveler has two derricks equipped with geared electric hoists. There are eight travelers which operate on different sections of the structure in batteries of four. The two interior tracks for the travelers and two exterior tracks for the cars are supported on concrete piers.

The dam site has been spanned by two 10-ton aerial tram cableways, each 1,860 ft. in length, the towers for which are seen in the background of Fig. 1. These are employed in an auxiliary capacity, principally to set the concrete block piers for the tracks and to raise the tracks as the work progresses.

Performance of Electric-Air Drills

It was desired to determine the cost and speed of drilling operations at the dam and quarry and for this purpose time studies were undertaken by the Construction Service Co. during the early part of the summer of 1913.

In general, the electric-air drill (Fig. 4) consists of two units, the drill proper and the pulsator. In appearance the drill closely resembles the compressed-air drill of corresponding size, having, however, a cylinder somewhat larger in diameter and with a shorter piston. It is mounted in the usual manner upon a tripod. The pulsator alternately furnishes air to either end of the drill cylinder and the same air is used over and over again in a closed circuit. Two lengths of rubber hose connect pulsator and drill, each acting alternately as supply pipe and exhaust. The pulsator is geared to a small alternating current motor, both mounted on a rigid truck to facilitate handling. Pulsator, motor, and truck weigh about 800 lb.

The ordinary air or steam driven rock drill takes a full cylinder of

air or steam at full pressure for each stroke, and exhausts to atmosphere at practically full pressure. No advantage, therefore, is taken of the expansive properties of the actuating fluid, which results in a certain amount of power being wasted without accomplishing useful work. The closed system of the electric-air drill, however, is filled with air under a low pressure, and this air is never exhausted, so that the expansive effect is turned directly to profitable account. Leakage is provided for

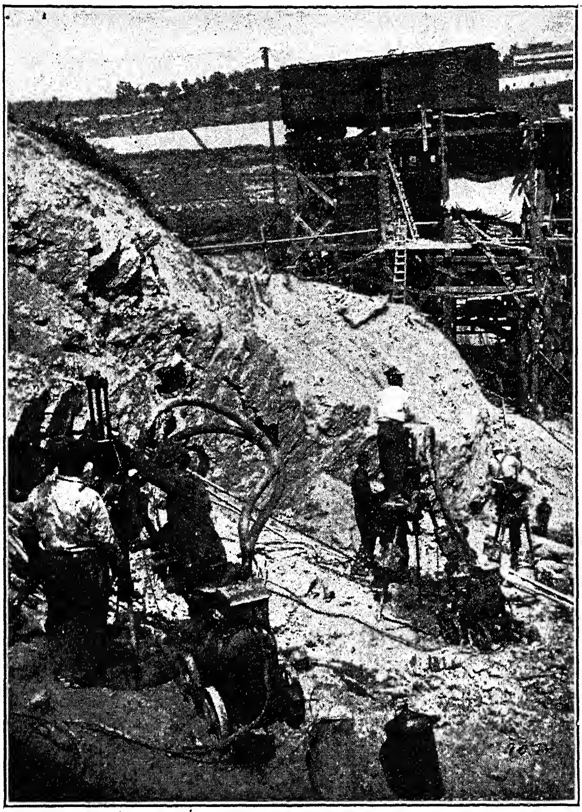

FIG. 4.—ELECTRIC-AIR DRILLS PUTTING IN HOLES FOR THE CUT-OFF TRENCH AT THE UP-STREAM SIDE OF THE DAM.
Changing steels on the Drill in the foreground.

by a compensating valve on the pulsator which automatically keeps the volume of air in the system constant. The drill has no chest nor valves and the pulsator has neither operating valves nor water jacket.

The drills observed are known as Temple-Ingersoll Type 5-F, and the pulsators are driven by motors rated at about 5 h.p., operating on 14.6 amperes at 220 volts. The cylinder diameter is $5\frac{5}{8}$ in. and the length of stroke 8 in. The length of feed, or depth of hole that can be drilled

without change of bit, is 30 in., but during observation the bits were usually changed after about 25 in. had been drilled. The strokes per minute were about 400 at full speed.

The drills were operated and handled by the drill runner and one helper and moving was accomplished by hand. The method of dismantling is about the same as with the ordinary tripod drill except that in the case of the electric-air drills there is the added weight of the mounted motor and pulsator to be moved.

The diameter of the starting bits was $3\frac{1}{2}$ to 4 in. and decreased $\frac{1}{8}$ in. for each succeeding length of steel down to $1\frac{3}{4}$ in. for the deepest holes. The steels varied from 2 ft. 6 in. to 28 ft. 8 in. The steels were octagonal in section, from $1\frac{1}{4}$ to $1\frac{1}{2}$ in., with square cross bits. The shorter steels were handled by one man and the longer ones by the driller and helper, sometimes with the aid of a hook.

Two forms of chuck were observed, one a bolted chuck, and the other consisting of a sleeve sliding on a tapered key and bearing directly on the drill steel. The time required to insert the steel in the chuck and to tighten the chuck was considerably greater in the case of the former type than in that of the sleeve type, as noted in the time study made at the quarry. Both types appeared to be equally efficient.

The spacing of holes at the quarry varied from 15 by 12 ft. to 20 by 20 ft. The holes were all vertical and varied in depth from 10 to 26 ft. The number of holes shot at the quarry depended upon the quantity of rock needed in the construction work. Generally, the method employed for cleaning the holes was to pour water into them and bail out with sand pumps when changing steels.

The sharpening shed at the quarry was situated some distance from many of the drills in operation, hence there were occasional delays in receiving sharpened steels, during which time some of the drills were idle. The steels were sharpened by hand at the dam and by a Leyner drill-sharpening machine at the quarry.

The smith's work consisted of sharpening the drills and also included other repair work. He estimated that 75 per cent. of his time was devoted to the drill steels. The estimate of coal burned by the smith was 500 lb. per day.

Sticks of 60 per cent. Dupont dynamite, $1\frac{1}{2}$ in. in diameter by about 8 in. in length, weighing 12 oz., were used. Dupont exploders were employed. The blasting charge at the quarry was calculated to average about $\frac{1}{2}$ lb. of dynamite per cubic yard of rock. The charge was set off by means of electricity. The blasting gang on the day of observation consisted of one loader and two tampers.

The oil consumption of the drills was about 3 quarts each per shift. The power consumption was from 30 to 40 kw-hr. per drill per shift. There was one 8-hr. shift per day.

Time Study of Drilling Performance of Electric-Air Tripod Drills at the Quarry

Observations recorded in minutes and seconds

	No. of obs.	Minimum M S	Average M S	Maximum M S	Actual time M S	Consumed time per cent. of total time
Drill cutting	16	5–40	14–18	23–28	228–54	51.1
Raising drill	15	0–05	1–05	1–59	16–13	3.6
Loosening chuck *a*	7	0–02	0–11	0–45	1–16	0.3
b	3	1–06	1–27	1–46	(4–20)*c*	....
Removing bit	12	0–03	0–32	1–54	6–26	1.4
Bailing hole	11	0–45	1–23	2–00	15–10	3.4
Putting bit in hole	12	0–10	0–22	0–55	4–20	1.0
Inserting bit in chuck	16	0–10	0–23	0–40	6–12	1.4
Tightening chuck *a*	6	0–05	0–10	0–20	1–00	0.0
b	10	0–38	0–53	1–20	8–46	2.8
Getting started	17	0–00	1–01	6–23	17–13	3.2
Cycle totals	......	8–44	21–45	41–30	305–30	68.2
Shifting drill	4*d*	35–32	52–00	60–00	73–18*e*	16.4
Miscellaneous delays	11	0–30	6–17	25–40	69–05	15.4
Total	......	....	....	....	447–53	100.0

Linear feet drilled, 31 ft.; average depth of holes, 22 ft.; total working time, 7 hr. 27 min. 53 sec.

a Sleeve chuck.

b Bolted chuck.

c This figure is not included in "Cycle Total" for this operation was performed by one man at the same time that the other man was raising the drill.

d During one observation a nearby derrick assisted in moving the drill, saving several minutes.

e Inasmuch as a shift was made after every 22 ft. of hole the time for shifting properly charageable is $\frac{31}{22} \times 52 = 73-18$. Several observations were taken simultaneously on different drills to ascertain a fair average time required to shift before deciding upon 52 min. as the average.

From the above table it appears that the average cutting speed was 0.135 ft. per minute. The ratio of cutting time to total time was 0.511 and the ratio of idle time (including the time for shifting drills) to cycle time was 0.467.

Based on the above performance at the quarry, the following costs per linear foot drilled and per cubic yard loosened have been deduced: 1 drill cut 31 ft. in 447 min. 53 sec.; equivalent to 200 ft. by 6 drills in

one day of 8 hr. The average spacing of the holes being 17.5 by 16 ft., the corresponding cubic yards loosened was

$$\frac{200 \times 17.5 \times 16}{27} = 2{,}070 \text{ cu. yd.}$$

Standard Basis of Costs

At the Quarry

	Rate	Amount		Cost per linear foot	Cost per cubic yard
				Cents	Cents
6 drillers	$2.50	$15.00			
6 driller helpers	1.75	10.50	$25.50	12.75	1.23
1½ blacksmith	3.00	4.50			
1½ blacksmith helpers	1.75	2.63			
2 nippers	1.50	3.00			
2 mules	1.50	3.00	$13.13	6.57	0.64
Total labor (drilling)	......		$38.63	19.32	1.87
Coal, 500 lb	3.50	0.87			
Oil, 3 qt. per drill	0.30	1.35			
Power, 35 kw-hr	0.01	2.10	$4.32	2.16	0.21
Total drilling cost	......		$42.95	21.48	2.08
Interest and depreciation, 2 per cent. per month.			7.70	3.85	0.37
			$50.65	25.33	2.45
3 powdermen	2.00	6.00			
1,035 lb. dynamite	0.12	124.20			
25 exploders	0.03	0.75	$130.95	65.47	6.32
Total	......		$181.60	90.80	8.77

In the foregoing no account has been taken of contractor's overhead charges, superintendence, storage, repairs, preparatory costs, insurance, charity, accidents, legal or medical expenses, etc.

The low cost per cubic yard is due to the unusually wide spacing of the holes, which were loaded with a heavy charge of dynamite.

Time Study of Drilling Performance of Electric-Air Tripod Drills at the Dam

Observations recorded in minutes and seconds

	No. of obs.	Minimum M S	Average M S	Maximum M S	Actual time M S	Consumed time per cent. of total time
Drill cutting.........	12	6–23	11–35	21–24	139–00	58.9
Raising drill..........	11	0–10	0–51	2–00	9–22	4.0
Loosening chuck.. ...	12	0–00*a*	0–09	0–25	1–45	0.7
Removing bit........	12	0–00*b*	0–29	1–10	5–42	2.4
Bailing hole..........	10	1–43	1–36	2–42	16–01	6.8
Putting bit in hole....	10	0–18	0–45	2–09	7–34	3.2
Inserting bit in chuck.	10	0–05	0–25	0–55	4–08	1.7
Tightening chuck.....	11	0–02	0–14	0–40	2–30	1.1
Getting started.......	10	0–02	0–13	0–45	2–08	0.9
Cycle totals..........	.....	8–43	16–17	32–10	188–10	79.7*c*
Shifting drill.........	2	9–03	12–00	15–00	28–48	12.2*d*
Miscellaneous delays..	8	0–15	2–24	9–40	19–12	8.1
Total.............	.....	....	....	....	.236–10	100.0

Linear feet drilled, 26.4 ft.; average depth of holes, 11 ft.; total working time, 3 hr. 56 min. 10 sec. The cutting speed was 0.190 ft. per minute; ratio of cutting time to total time was 0.589; ratio of idle time (including shifting of drills) to cycle time was 0.255.

a Chuck loosened by one man simultaneously with raising of drill by other.

b Bit removed by one man simultaneously with raising of drill by other.

c The percentage of "Cycle Total" is higher in this case than at the quarry, due mainly to the fact that the delivery of sharpened steels to the drillers was more prompt.

d For the same reasons as given in the note under "Shifting Drill" in the quarry time study, the time for shifting properly chargeable in this case is $\frac{26.4}{11} \times 12 = 28 - 48$.

Based on the performance, at the dam pit, of one drill doing 26.4 linear feet in 236 min. 10 sec., six drills would accomplish about 320 ft. per day.

During observation, the spacing of holes at the dam was very irregular. The diagram (Fig. 5) shows the approximate spacing of the holes at the time this observation was made. The drills were at work on the cut-off trench on the up-stream side of the dam. The wide cut, at a rough estimate, appeared to be nearly 200 ft. in width, but the cut-off trench was only about 15 or 16 ft. in width and averaged about 11 ft. deeper than the main cut. The spacing of holes was very close and the blasting charges were correspondingly light. The outer rows of holes had a spacing of only 6 in., which resulted in practically smooth walls.

The total drilling cost at the quarry for six drills per day was $50.65,

including interest and depreciation. On the same basis of costs, the performance at the pit would be at the rate of $\frac{\$50.65}{320}=15.8$ c. per linear foot, as against 25.33 c. at the quarry. Of course, for comparative purposes, the blasting costs should be omitted, inasmuch as the amount of powder per linear foot would be much lower at the dam, due to the closer spacing and lighter loading of the holes.

For similar reasons, and because of the irregular spacing at the pit, there would be little value in a comparison of costs per cubic yard

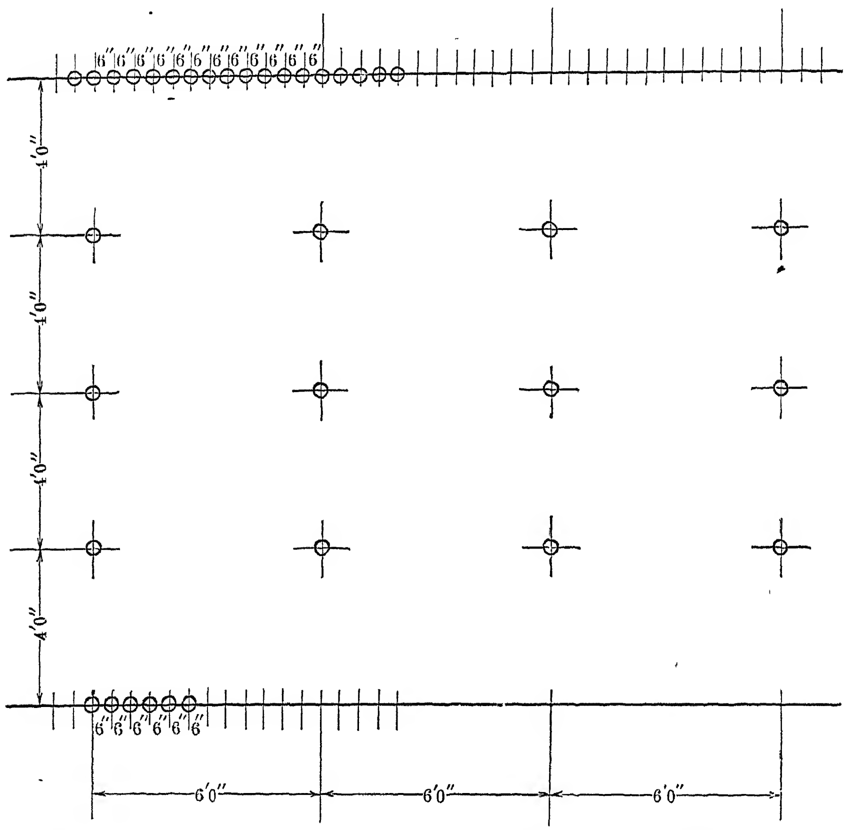

FIG. 5.—APPROXIMATE SPACING OF HOLES IN TRENCH FOR DAM FOOTING.

excavated. The cost per linear foot drilled is less at the pit than at the quarry for the reasons that the cutting speed was greater and the ratio of cutting time to total time was greater.

Electric-Air Drill Wagons

The electric-air drill wagons are putting in holes averaging about 40 ft. in depth. The holes are started at 5 in., and bottom at 3½ in. A cross bit is used.

The drill wagon (Fig. 6) is supported on heavy planks placed on the ground, so that it is a very simple matter to advance the wagon when a new set of holes is to be put in. Several holes may be drilled at one setting of the wagon as the drill mechanism is mounted on a circular rotatable platform, allowing holes to be put in on either side and beyond

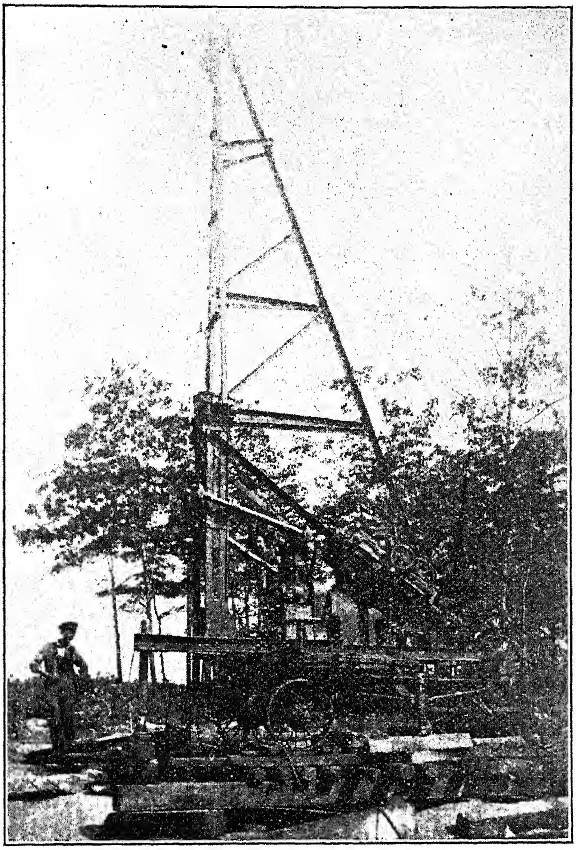

Fig. 6.—One of the Electric-Air Drill Wagons at the Quarry.

the end of the wagon. The drill wagon has a vertical power feed of 6 ft., the drill traveling up and down in vertical guides, while a lighter and higher frame is used as a hoist for the steels. It takes them out of the hole at a single lift, excepting the very longest steels. The drill cylinder is 7 in. in diameter, 7 in. stroke, and strikes 350 blows per minute.

The pulsator and 12-h.p. electric motor operating it are both mounted on the drill wagon. In other respects the arrangement and operation resemble the Temple-Ingersoll tripod drill outfits.

By means of clutches, the motor drives the feed screw for the drill hoist and raises and lowers the steels; it also operates a winch which can be used to propel the wagon when its position must be changed.

One drill runner and a helper operate and handle the drill wagon. The shifts are of 8 hr. duration and at the time of this observation the drills were averaging about 40 or 50 ft. of hole per shift. The weather was most oppressively hot during this particular observation, which probably accounted for the relatively slow progress, as it is understood that the progress of drilling in this rock has usually averaged 45 to 65 ft. per shift and, under test conditions, as much as 104 ft. of hole has been drilled per shift. A constant stream of water is fed into the hole through a pipe beside the steel. A long bamboo pole is used for lowering the blasting charge into the hole. Electricity is employed for setting off the charges, and, as parties are working simultaneously in various parts of the quarry, the blasting can be carried on in one place while the drilling and mucking are in progress in other sections of the quarry.

The Geology and Ore Deposits of the Bully Hill Mining District, California*

BY A. C. BOYLE, JR., LARAMIE, WYO.

(New York Meeting, February, 1914)

CONTENTS

* Submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, in the Faculty of Pure Science, Columbia University, December, 1913.

I. Introduction

The geological field work of the Bully Hill district, upon which this paper is based, was begun July 1, 1908, and covered a period of three months. The time was found too short for a complete report and the district was again visited in the early part of July, 1912, from which time detailed study of the locality continued until September of the same year. This paper is the result of observations made in the mines in the immediate vicinity of Winthrop, Shasta county, Cal., during these two periods of study.

The preparation of this report has been greatly facilitated by various courtesies rendered the writer by D. M. Riordan, President of the Bully Hill Copper Mining & Smelting Co., and by John B. Keating and Herbert R. Hanley, managing officers actively in charge at the mines. The elaboration and further study of the notes and collections were carried on in the laboratories of the Departments of Geology and Mining at Columbia University, and the writer takes pleasure also at this point in expressing his acknowledgments to Profs. James F. Kemp, A. W. Grabau, Charles P. Berkey, and William Campbell, for advice and assistance.

In order that one may appreciate at first reading the significance of some of the details which follow, and for the sake of clearness, a brief outline of the geological relationships is here given, together with certain conclusions which have been reached regarding the genesis of the ores and the gypsum masses.

In the Bully Hill mining district an associated series of Triassic lavas and tuffs, chiefly andesites, is preceded as well as followed by sediments. The entire system is tilted so that the original bedding planes dip in general to the southeast. The surrounding region has been greatly disturbed, and in the immediate vicinity of the mines close folding of the later sediments and extreme shearing of the igneous rocks locally is a striking feature.

Into the nearly vertical shear zones have been intruded post-Triassic dikes of various rock types in the following order: alaskite-porphyry and andesite-porphyry. Outside the area under consideration diorite dikes are known, but they will not receive attention further than to note that they probably represent a differentiation product of the same magma from which the other two dikes came. In this connection all the dikes have an important bearing on the origin of the ores and of the gypsum found in the mines.

The intrusion of the alaskite-porphyry as well as the later andesite was accompanied by the emission of magmatic waters and metal-bearing solutions. As these solutions passed upward they wrought important changes in the rocks within their influence, and were directly responsible for the introduction of the various ore minerals, as well as some of the

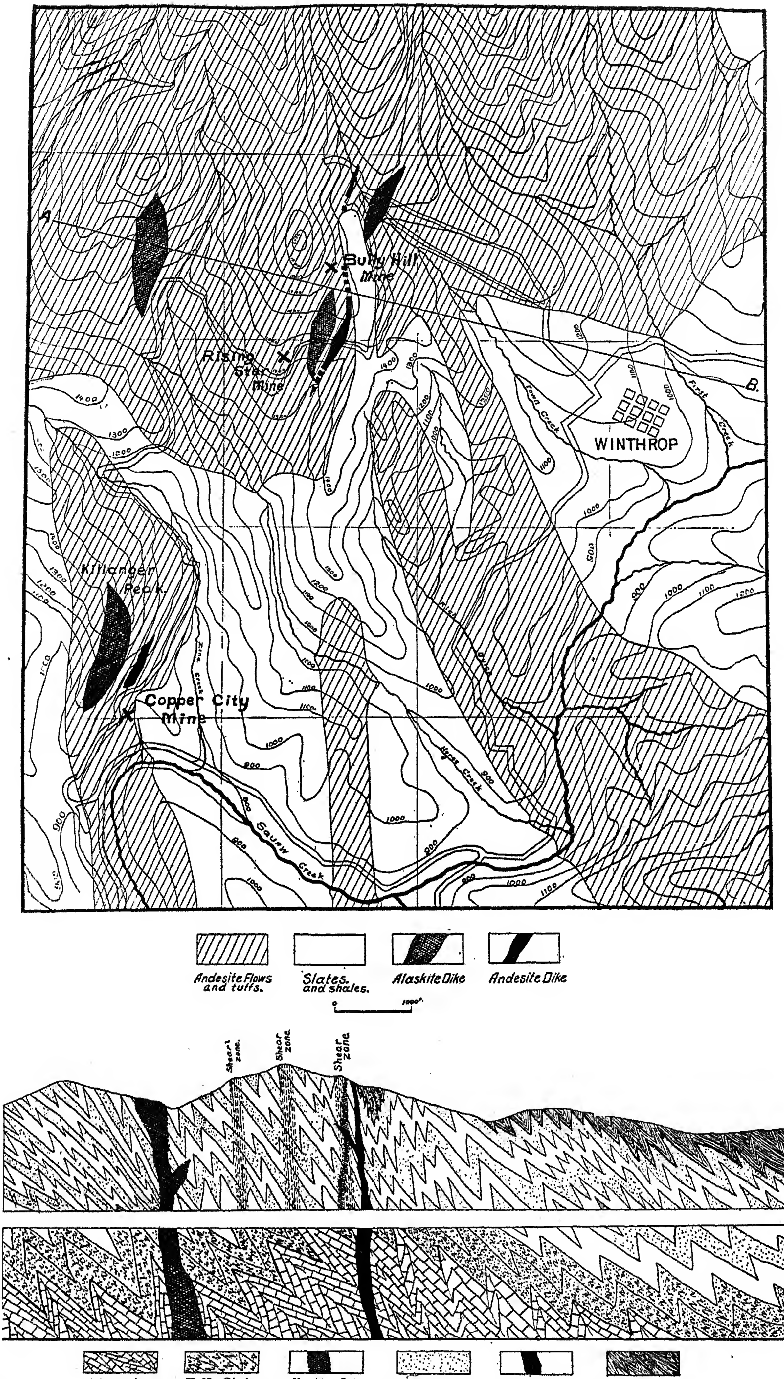

FIG. 1.—MAP OF BULLY HILL MINING DISTRICT, WITH GENERALIZED SECTION ON LINE A–B.

ie lower structural section is below sea level and involves the McCloud Limestone.

gangue. By secondary changes which involved alteration, the ores became enriched so that in some cases a copper content of 8 per cent. was produced.

Of considerable interest in this district are the relationships between the shear zones and the various dikes; the shape, extent, and genesis of the ore bodies; the occurrence of large masses of sulphate of lime, which suggests formation by a process not heretofore recognized of great importance. Of great economic significance are the association of copper ores with the alaskite-porphyry, and the interpretation of some facts established in prospecting the extensive masses of gypsum.

The area covered by the map, Fig. 1, extends 2 miles east and west and 3 miles north and south. It is embraced in the *Redding Folio* of the U. S. Geological Survey, which was prepared by J. S. Diller, to whose careful observations the writer is deeply indebted. The recent development of the mines has naturally revealed, however, some points of interest which were not accessible when Mr. Diller's observations were made, and as a result some modification of his views will be supported.

II. Location of the District

The Bully Hill district is one of several mineral belts situated in a moderately elevated area in the western central part of Shasta county, Cal. This county lies at the extreme northern end of the Great Valley of California and embraces a range of mountains which is chiefly formed by the northward convergence of two important mountain chains, the Sierra Nevada on the east, which has a general north and south trend, and the Coast Range on the west, which has a decided northeast trend. The actual junction consists of short irregular ranges.

The section of the country is roughly in the shape of a flat-lying U with the opening to the south. The Coast Range and the Sierras form the limbs, while the high slope of the Sierras, bearing westward, rapidly merges with the eastern slope of the Coast Range and produces the gentle curve of the U at the north.

Irregular east and west ridges parallel to the curve of the U succeed one another to the north, and present a relatively steep front to the south. The Southern Pacific railway, connecting Sacramento with Portland, passes up the Great Valley and crosses this range by following along the course of the Sacramento river and its tributaries. At a distance of 10 miles north of Redding it passes through the station of Pit, from which the Sacramento Valley & Eastern railway extends to the east 15 miles so as to tap the copper belt at Copper City. The branch finally ends 3 miles farther to the north at the Bully Hill mine, near the town of Winthrop.

The productive area which has attracted attention for the past 13

years and which is now under consideration lies in the immediate vicinity of the town. There are three local mining centers, designated as Bully Hill to the north, Copper City to the south, and the Rising Star between these, but somewhat nearer to Bully Hill.

History of the Mining Development

The existence of copper ores in this part of the mineral belt was known in the first decade of the '50's. It was encountered in small quantities in tunnels which were opened primarily for the gold and silver veins which yielded the placer values. In 1853 placer gold was discovered in the vicinity of Bully hill[1] and in 1862 gold was found in the altered surface rock near the present site of Copper City.[2] The copper deposits were neglected for the time being, and little of importance happened before 1895.

Oxidized ores from the surface soon failed to yield acceptable returns, and tunneling was employed with the hope of discovering sources which presumably supplied surface values. Tunnel No. 1, on the east slope of Bully hill about 500 ft. from the top, was driven a short distance. Since the surface somewhat to the west and north had yielded profitable returns in gold and silver, this tunnel was driven with a view to striking the gold-bearing rock in depth. As the working face advanced, the gossan which had yielded the values changed into very base ore. This condition of affairs so discouraged the operators that in a comparatively short time their workings were abandoned, as it was the general belief that such base ores could not be reduced successfully.

About this time Iron Mountain, some 20 miles to the southwest, was located as an iron mine by William Magee and Charles Camden. The surface rocks throughout the entire country were more or less stained by iron oxide; the gossan was thick and usually carried gold values. Practically the same gossan occurred at the abandoned claims on Bully hill. Since sufficient time had elapsed for the timbering in Tunnel No. 1 of Bully Hill to rot, the property was relocated and later passed into the possession of Alvin Potter, in 1877. The tunnel was reopened and retimbered. Some ore was taken out, but it exhibited such a base character that active work was discontinued, and subsequently the property passed into the hands of the Extra Mining Co.

It now appeared for the first time that the enterprise was on a firm basis, and in 1877 the first ore-dressing mill in Shasta county was erected near the present site of Copper City by C. M. Peck. The mill was erected on the west bank of Squaw creek and was known as the Northern Light mill.

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[1] *Bulletin No. 23, California State Mining Bureau,* p. 32 (1902).

[2] *Idem,* p. 33.

It is reported that in three years the company extracted nearly $650,000 from the ores. The rich values soon began to decrease or change in character to such an extent that this mill was abandoned after a comparatively short period of operation. The equipment became the property of Messrs. Potter and Hall, who had purchased some of the adjoining claims, but, like the Extra Mining Co., they were forced to discontinue operations because of the complex nature of the ores.

The entire milling industry was established on the basis of returns from a 250-ton shipment of local ore sent to Swansea in 1863. It is reported that the ore assayed 8 per cent. in copper, and showed a value of $40 in gold and $20 in silver to the ton. The copper content was considered of no value.

In 1879 James Salee passed through this section of the country and incidentally visited Iron Mountain. He was a miner of wide experience, and in samples of the gossan which he had collected he found gold and silver values. He became the sole owner of the property at Bully hill. Years passed and occasionally new finds would be reported, which boomed the Copper City district and gave a new impetus to speculation. Little was done, however, until the latter part of the '90's, when the property was transferred to the Bully Hill Mining & Smelting Co. Such is, in part, some of the early history of the camp.

Topography

The district shown on the map, Fig. 1, is embraced by the Klamath mountains and shows a well-dissected portion of the Klamath plateau. The elements of relief are not many and are easily distinguished. Topographically the most important feature of this region is a ridge of igneous rock formed by the upturned edges of surface flows of andesites and intimately associated tuffs. This complex has been metamorphosed to such an extent that it resists erosion to a greater degree than the limestones to the northwest, on which it rests, and than the shales and tuffs which flank it on the south and east. This ridge is continuous outside the limits of the map for a distance of 30 miles and has approximately a north and south direction.

In general, the drainage of the district is to the southwest until the Sacramento river is reached, after which it is entirely south. To the east of the ridge is Squaw creek, which flows southwesterly and joins Pit river near the southern border of the map. The west slope of the ridge is drained entirely into the McCloud river. This ridge is traversed by a series of narrow and steep gulches separated by steep ridges of a minor order.

Bully hill may be regarded as an elevation of secondary importance, scarcely more than 2,000 ft. in height. The elevations decrease pro-

gressively toward the southern limits of the map. The topography is intimately related to the general geological structure of the district and results from differential erosion of the various rock formations.

The lower portions of the larger gulches have been partly filled with detritus from the higher slopes, and in many parts of the district these have been worked as placers.

III. Stratigraphy

It is not the purpose of this paper to enter into an elaborate detailed discussion of the stratigraphy of the region, for it has received great care and special attention from J. S. Diller,[3] J. P. Smith,[4] and H. W. Fairbanks.[5] In order, however, that the geological relations of the eruptive rocks and the ore bodies may be fully comprehended, a brief outline of the separate formations is here introduced. (See Fig. 2.)

The oldest rocks in the Bully Hill district which outcrop on the surface consist of a series of volcanics, everywhere tilted at a high angle decidedly to the southeast, although locally beds may vary so as to be nearly flat.

This series consists of alternate flows and tuffs which together measure roughly 1,500 ft., and has been named by Diller[6] Dekkas andesite. Above this and apparently conformable are the crumpled massive to thin-bedded shales of the Pit series. Only the lower part of fully 2,000 ft. of the Pit shales is embraced by the eastern boundary of the map.

Description of the Rocks

Triassic Lavas and Tuffs.—Andesite flows and related tuffaceous beds, now greatly metamorphosed, are seen to cover most of the western part of the area under consideration. The shape and areal distribution are shown on the map, Fig. 1. It is a matter of some difficulty, however, to fix the precise divisional planes that separate the earlier from the later flows. This comes about from the fact that one grades into the other. In many instances the flows succeed each other with apparent regularity, and at times were followed by accumulations of tuffaceous materials. The present metamorphosed condition of the tuff beds and the flows makes it difficult to draw definite divisional planes. From the manner in which this andesite series weathers it is possible to describe two different varieties, but because of limited space the andesites collectively will be described as a single unit.

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[3] *Redding Folio, No.* 138, *U. S. Geological Survey* (1906).

[4] The Metamorphic Series of Shasta County, California, *Journal of Geology,* vol. ii, No. 6, p. 588 (Sept.–Oct., 1894).

[5] Geology and Mineralogy of Shasta County, *Eleventh Report of the California State Mineralogist,* p. 24 (1892).

[6] *Redding Folio, No.* 138, *U. S. Geological Survey,* p. 7 (1906).

The freshest specimens are dark gray, with numerous small glistening phenocrysts of labradorite, showing best on fractured surfaces. The rock exhibits a greenish tinge, due to the presence of chlorite, epidote, and similar secondary minerals derived from pyroxenes (probably augite). On alteration the rock usually becomes lighter colored, and in many places on first sight resembles rhyolite. Occasionally sparsely scattered vesicles which have been filled with calcite occur, and the presence of these gives

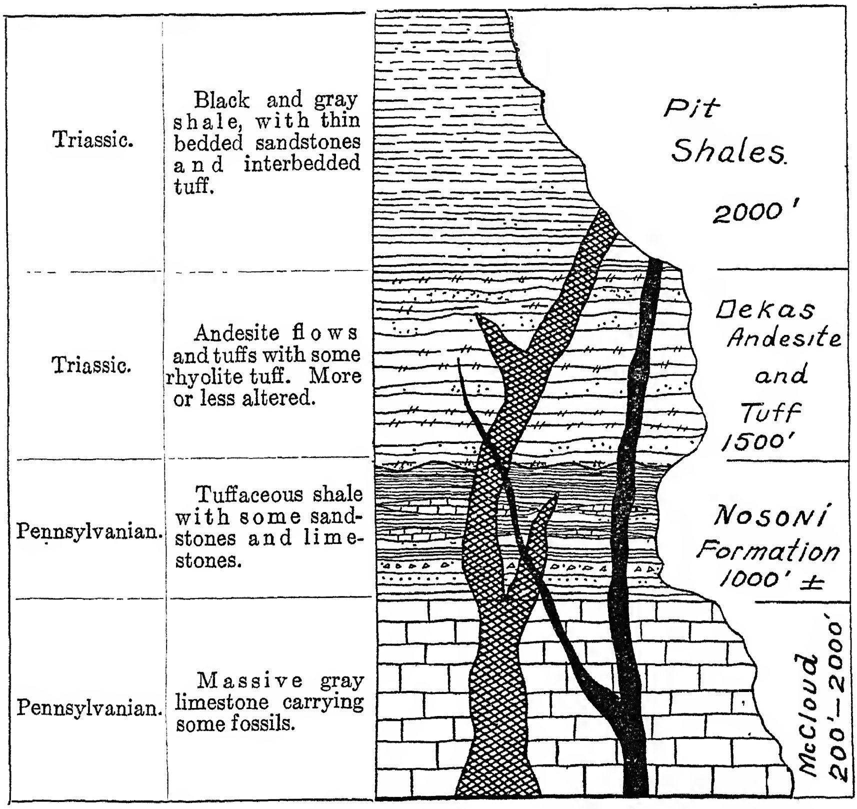

FIG. 2.—GENERALIZED COLUMNAR SECTION IN BULLY HILL DISTRICT, SHOWING THE INTRUSIONS.

to the rock mass a mottled appearance. Where the rock is found thoroughly altered it is characterized by a red stain derived from iron-bearing silicates. The secondary minerals are sericite, quartz, kaolin in large amount, and minor quantities of calcite and iron oxide. The alteration is often attended by leaching by which the rock changes to a nearly white mass, roughly schistose.

In the valleys where this andesitic material has accumulated characteristic red gravelly soil results, which because of the red color makes it

impossible to trace the series where the outcrops are obscured. The massive character of some of the flows is evidenced from the presence of numerous large rounded boulders, which are to be seen in the gulches as placer gravels.

Triassic Sediments.—The Pit Shales.—The youngest formation in the district with which this paper is immediately concerned is an extensive series of shales, interbedded occasionally with various volcanic tuffs. In general these shales are fine-grained, dark gray to black, characteristically thin-bedded, and frequently provided with remains of minute marine organisms.

This terrane is by far the most extensively developed of any formation in the district and covers the entire area of the eastern part of the map. These shales underlie a limestone having an abundant and well-preserved fauna which is known to be Middle or Upper Triassic.[7] Because of this relationship the age of the shales is placed in Middle Triassic.

The average strike is north and south when large areas are considered, but on the map it will be noted that the strike varies. The dip is decidedly to the southeast, in common with the previous series, and in amount it is not far from 28°. Variable dips are encountered in the southeastern part of the map.

Where the shales exist the topography is well rounded, and usually low lands result. This is not because the series is characteristically soft, for there are some members making up the deposit which are hard and resistant; but because a few soft layers or beds exist. These are usually tuffs, and as they are washed away the harder parts, because of insufficient support, break away and the entire formation is thus weakened and the topography is thereby subdued.

The rock types include brownish red to yellowish red shales and tuffs. The shales alter to lighter shades, browns and grays predominating. Because of folding the entire formation is jointed and shattered, and overturned folds are not uncommon.

Areal Geology

The area mapped consists of Triassic rocks, which can be deciphered into several distinct types. Along the southern and eastern border of the map are found sediments, chief of which are shales, sandstones, and interbedded tuffs. The area embraced shows only a small part of a widespread series which extends north and south for many miles, and stretches over a distance of 10 miles or more in width to the south. The western border of the area is rather irregular, a condition produced in part by stream cutting, but largely by complex folding and erosion.

West of the sedimentary portion is an extensive area of igneous rocks

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[7] *Professional Paper No. 40, U. S. Geological Survey*, p. 16 (1905).

comprising andesites and andesitic tuffs. These rocks cover the entire west half of the area under consideration. Irregular masses and long strips extend south and east from the main area. The entire area has been sheared so that the rocks are usually of a pronounced and thinly foliated type. Into the sheared country rock have entered dikes, which tend to complicate the structure. Natural outcrops are abundant and form sharp ridges, persistent for long distances. The hilly tract containing the mines embraces this igneous complex and has abundant evidences of mineralization. The ledges of altered andesite and dikes rise many feet above the general profile, and obviously present what physiographers term a "young" topography. The rocks over wide areas are greatly decomposed, and, except where exposed as already described, have weathered to a mantle of soft, reddish brown, chalky débris; and again they have become so thoroughly silicified that their original character is entirely obliterated. The extent and general areal relationships are given on the map, Fig. 1.

Structure

The rock formations, which have a general southeasterly dip, are complicated by folds, faults, shear planes, igneous intrusions, and metamorphism to such an extent that in the immediate vicinity of the mines these secondary features are of more importance, in the solution of the problems later discussed, than the rock types in which they are so conspicuously found.

In order that the significance of these relations may be fully comprehended, and also that the reader may have at the outset a working knowledge of the local features, it becomes necessary particularly to appreciate the character of the various metamorphic processes involved. There is a very intimate relation between all these elements and the origin of the ore deposits. No single feature when taken by itself explains the situation, but when all are taken together, in proper sequence, they are directly responsible for all the facts observed with regard to the ore genesis. For convenience and emphasis these will be discussed separately.

Folds.—The best preserved folds are to be seen in the sedimentary rocks which flank Bully hill on the south and east. In these rocks the compressive forces have produced a great variety of folds, ranging from those in which the flexure is just perceptible to those where overturning is pronounced. The folds are complicated, variable, and at times very obscure. The simplest type, Fig. 3, is found in the south and east part of the area, and the folds become progressively more complicated north and west until at the contact with the igneous rocks they are apparently lost by grading into another structure later to be discussed.

The prominent phase of deformation especially noticed in the vicinity

Fig. 3.—Open Folding in the Pit Shales.

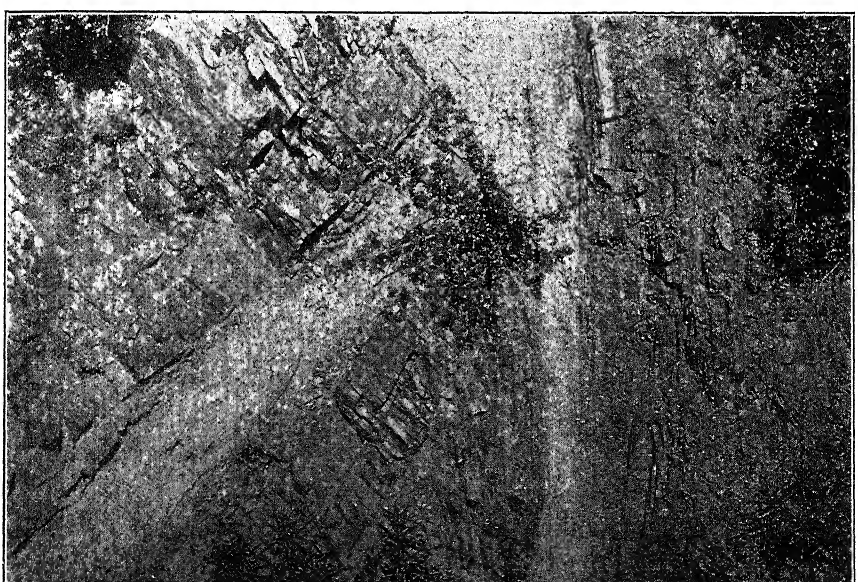

Fig. 4.—Close Folding in the Pit Shales.

of the mines is that which follows from compression. Within this zone the strata have shortened and the greater length of the various beds, previously listed and described, has been taken up by folding. The bending became complex and later reached a condition in which the units yielded easier to the applied stresses by breaking than by further crumpling. As a result, in the western part of the Pit shales, the adjustment is characterized by numerous breaks in the strata. Since the strata of the Pit formation consist of shales, sandstones, and limestones, there is reason to suspect widely differing structures.

The composition and thickness of the various beds determined in a large way the behavior of the series under the applied stresses. The units varied greatly in thickness, and as a rule the thicker portions yielded by breaking rather than by bending. On the other hand, where the strata were thin and the composition favorable, complex folding and contortion resulted. These finally became more pronounced and were later replaced by thrust and dislocation.

Everywhere the Pit shales are folded, and so prominent is this feature that the formation can be detected for great distances. These strata were not originally deposited in this position, but have been subsequently deformed by lateral thrusts which crumpled the units and caused the folds. As might be expected, folds occur of every degree of complexity. Some are broad and open, others are narrow and compressed; in some the strata are but slightly disturbed, in others the beds are actually twisted, contorted and confused in the most extraordinary manner. (See Fig. 4.)

The whole process is not difficult to imagine, and it is furthermore an absolutely necessary step to follow if one wishes to understand the structural relations in the mines as they now exist. Many of the local complexities observed in the working places are easily understood and can be explained by a knowledge of the structures.

It should be stated that in few places only, in the field directly related to the mines, are there good examples of complex folds in the tuffs. This is not because these have in any way escaped the deformation, but chiefly because extreme shearing and metamorphism have obliterated all evidences of such features.

The greater part of the hill in which the mines are located consists of a series of interbedded andesites, and associated tuffs. Although there is a wide range between these products they show a common behavior in the development of shear and foliation. Over the entire region, of which the area mapped is a small part, there is a likeness in the results that argues similarity of causes and materials.

The units varied greatly in thickness from point to point and often the tuffs were mixed in and incorporated with the flows. The fragmental volcanic rocks appear to have been very abundant and may even have

been predominant in this particular locality. As such they consisted mainly of fine dust particles, but there is evidence also that large amounts of ash, as well as some glassy fragments, constituted part of the accumulations.

The massive brittle rocks were originally the flows and these have furnished the angular fragments of the breccias, while the tuffs, because of their porous texture, permitted adjustment to take place between the individual particles without apparent crush. In extreme zones of shear and brecciation, however, all traces of former structures have been obscured, if not completely obliterated. The composition and form of the volcanic rocks determined to some extent their behavior under the applied stresses. Since there is such an abundance of folded structures in the sedimentary formations on top of the igneous rocks, and a short distance to the west in formations stratigraphically lower, it follows that these deformations exist in some form, however badly preserved, in the igneous rocks as well, because the entire series was subjected to the same stresses and behaved as a structural unit. Just how far these deformations extend in depth is a matter purely conjectural, but it is believed that they have affected rocks very early in the geological column.

As noted above, the general structure of the district is comparatively simple, but there are minor features which tend to complicate it. As a result of the degree of folding, beds which were in the beginning far below have been brought near to the surface. These relationships are shown on the structural section taken along the line *A–B*, Fig. 1. Actual measurements at depth could not be made, but the surface relationships are mainly correct. As will be seen, the structural section is made in a line which is parallel to the direction of thrust and consequently the axes of the folds in the slates and the more complex shear zones in the igneous rocks trend northeast and southwest. Furthermore, the axes of the folds pitch, so that the tendency is for the ore bodies to pass into deeper rocks going northward.

Faults.—The structure of the district is affected only in a very subordinate way by faults, but where these do occur they are a source of further complexity. Since the readily distinguishable beds found in the immediate vicinity of the mines show no evidence of extensive faulting, it is safe to infer that no dislocation has taken place since these were laid down. It is possible, however, for faults to have taken place in the earlier rocks and yet not be registered in the sediments within the area mapped, but field study does not reveal any. There are numerous minor slips and dislocations in the rocks, but these are attributed to shearing processes.

Such slips have been encountered in prospecting work, but they are too local to be recognized as being important in the larger structural features, and they are too numerous to be shown on the map. In the

mine workings the older fractures have been rehealed, while the later cracks are still open and furnish circulation channels.

At only two points has faulting taken place on a scale that merits attention, and even here the data are somewhat obscure, so that the actual amount of dislocation is questionable. Further developments may reveal some interesting relationships. The shear zones which stand up as silicified ledges on the hill-top apparently end in the south slope of the hill. It is quite possible, however, that these shear zones are local; but there are several dikes, which will receive attention under "Intrusives," which also outcrop on the south slope of the hill, and these also end rather abruptly. After apparent shifting to the west about 100 ft., they continue in their normal direction southward and finally disappear under the shales. This is very suggestive of a fault when taken in connection with the dikes and the shear zones, but the shales only a short distance to the east show no evidence whatever of any dislocation.

Another possible fault, which is better characterized by being a "crush zone," is seen on the north slope of the hill where it crosses Town creek just northwest of the main tunnel entrance and back of the company houses. Here the rocks are badly brecciated and the zone is apparently vertical and at right angles to the foliation planes of the rock masses on each side. This zone has been partly explored in depth and some ore obtained. Aside from these two instances (and they are rather obscure) no faults of importance were found in the district.

Shear.—A structure which is intimately related to the folds and thrusts is that of shear. It may be regarded as the limiting phase of combined folding and thrusting processes. In this district sheared structures are prominent and are almost wholly restricted to the igneous rocks. While the massive igneous rocks show this structure to some extent, it is best developed in the tuffs, and in some of these it is so persistent that the rock in places may be regarded as typically schistose.

Just as the shales are characterized by being folded rocks, in like manner the igneous members can be considered as sheared rocks. Just where folding ends and shear begins is not always easily determined, since one passes by gradual transitions into the other. In a general way shear is characterized by being a finer structure and represents a greater degree of crush, and involves changes other than those of purely dynamic character. That folds and thrusts preceded shear in the igneous rocks there can be little doubt, but the persistent type structure now seen is shear alone.

The shear has developed mainly at right angles to the direction of pressure and has a general trend corresponding to a north and south plane. In the district under consideration the shear has taken place on a small scale in all the rocks and is widespread, but there were conditions which favored localized shear zones, and as a result Bully hill is char-

acterized by three independent zones which are approximately parallel to each other but separated by intervals of several hundred feet. These zones are nearly vertical and have a north and south direction. They are seen as irregular ledges which project above the general profile of the hill and are shown in Fig. 5. The material constituting the rock of these ledges is mainly silicified andesite tuffs and flows. In this hardened condition it resists the weathering processes and gives rise to rugged, steep slopes. In spite of the rock being hard it splits easily in a plane parallel to the foliation and is often characterized by an abundance of long parallel cracks trending north and south.

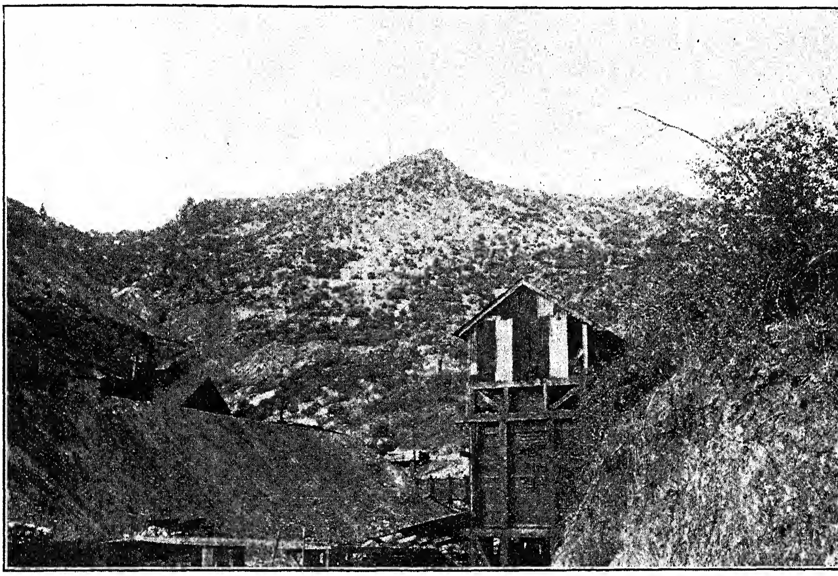

FIG. 5.—LOOKING NORTH FROM KILLANGER PEAK AT BULLY HILL.
The picture shows the three shear zones.

The Intrusions.

From observation of the succession and character of the intrusives of the district they present in their structural relations one single type—dikes, which are found well exposed on the southeast slope of Bully hill. They may be divided into two distinct varieties, an earlier acidic (alaskite-porphyry), and a later one of andesitic characteristics.

Alaskite Dike.—The alaskite dike, Fig. 6, is found in detached masses on the east slope of Bully hill and apparently ends at the Rising Star mine, 0.75 mile farther to the south. The rock is medium even-grained and contains a few small phenocrysts of quartz and feldspar in a fine-grained ground mass of mottled gray color. The freshest specimens

have practically no dark silicates. Most of the outcrops exhibit alteration and intense bleaching, so that the weathered, rough, projecting masses are colored by iron oxide, the colors ranging usually from yellows through reds to pinks.

In the hand specimen the actual dimension of the grains is seldom greater than 5 mm. Much of the rock is fine-grained and may be regarded as felsite-porphyry. Of economic significance are the nearly vertical foliation planes and the cracks along which ore-bearing solutions have deposited ores in notable amounts.

The time of the intrusion is not definitely known, but since the

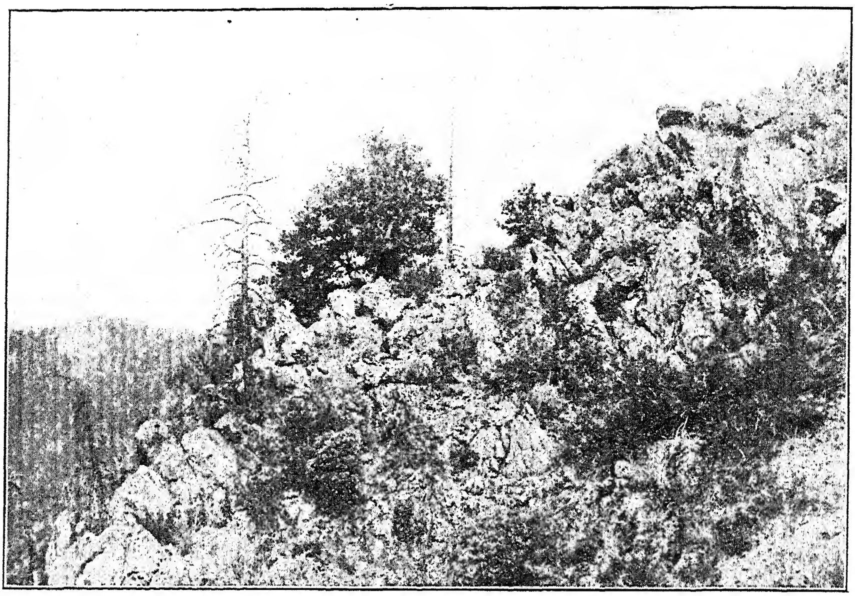

Fig. 6.—View Showing the Rugged Character of the Alaskite-Porphyry.

country rock is believed to have accumulated in Middle Triassic time, it follows that the intrusion is as young at least as the late Triassic.

Andesitic Intrusion.—A later intrusive of decidedly andesitic affinities, mostly decomposed to a reddish brown exfoliated mass, is exposed on the south slope of Bully hill and extends in a more or less continuous mass in a northerly direction for a distance of 0.75 mile. Because of the readiness with which this dike rock alters, it is mostly obscured, and at times it is difficult to distinguish it from the country rock through which it passes. Were it not for the exposures in ravines and gulches one would notice little difference between this rock and the normal weathered country rock.

The main body of the dike is nearly vertical, irregular, parallel or nearly so to the alaskite dike, and at several points it is coincident in

course with the direction of the main ore bodies. In the deeper workings of the mines it is known to have a thickness of approximately 300 ft. To the south of the Rising Star mine it pitches under the shales and disappears.

In the hand specimen it is greenish to grayish in color and is usually very fine-grained, although at times it is coarse enough to show distinct phenocrysts. It frequently exhibits amygdaloidal structure. The cavities in all cases are filled with calcite.

In common with the alaskite this dike sends off branches which undergound give considerable trouble and annoyance in mining operations. Some of the smaller branches are finely felsitic in texture.

The dike has been changed by shearing and alteration, so that in the mines the dike material exactly resembles sheared masses of ore. With reference to the age of this intrusion, it is the youngest igneous outbreak found in the district mapped, and although a definite age cannot be assigned to it, it is known to intersect the lower members of the Pit shales and therefore must be as young at least as the series, which is considered as Upper Triassic.

IV. Petrography of the Rock Types

The chief object of the microscopic study of the rock types has been to identify them and to suggest processes directly connected with the genesis of the deposits. Although the metamorphism is complex and the processes of mineralization have persistently overlapped other stages, it is believed that the best results will be obtained by attempting, as far as possible, to treat the various stages as individual and separate phases even though the several processes have been simultaneous.

The specimens of rock have been collected in a systematic study of the Bully Hill district, and represent quite fully the range of types. In the set of rocks which has been selected as typical, microscopic study shows the following: (1) andesites, andesite tuffs, and some rhyolite tuffs among the pyroclastics; (2) alaskite and andesite as the representatives of the intrusives.

Tuffs, of both the andesitic and the rhyolitic varieties, are the dominant types and include 11 specimens of the total 24. Next in importance are the andesitic flows which give rise to the breccias. Then follow the intrusives, which can be grouped into two main types: extremely acid and moderately basic.

The phases of mineralization may be listed under several different heads, but this arrangement does not mean that the processes necessarily followed one another in definite sequence. Aside from dynamic changes, a study of thin sections shows that all of the following processes have been operative in producing the present characters in the rocks and ores.

They are: sulphatization, carbonatization, sulphidation, chloritization, serpentinization, and silicification.

Andesite Flows

The andesites range in texture from distinctly porphyritic to finely felsitic and glassy varieties. The characteristic andesite is a close-textured, dense, grayish to greenish rock containing visible phenocrysts of feldspar in a greenish ground mass. The representatives of this class accumulated as thick flows, in some of which crystallization was well advanced before movement ceased.

The felsitic and glassy varieties are without doubt those which were poured out on the surface as thin flows and sheets. In some of these the escaping gases have left the mass porous, but this feature is not always prominent. The microscopic features show the porphyritic varieties to consist of labradorite with some hornblende in a felsitic ground mass. The feldspars are large and contain numerous scattered inclusions, presumably ilmenite. In the finer-grained varieties the feldspar and hornblende wane and in the glassy facies these minerals entirely disappear.

Only fragmentary evidences of biotite remain and in the highly altered types this is often indicated by the arrangement of grains of magnetite.

The transition of the porphyritic types to the finer-grained varieties is gradual but distinct. The alteration of the andesites is a very salient characteristic. Aside from the ordinary weathering to chlorite, kaolin, and epidote, some sericite was noticed, especially where the rocks were badly crushed. Some of the larger phenocrysts of feldspar show internal strain, as seen in the wavy extinction. Where the crush has been extreme the phenocrysts are badly broken and comminuted. The glassy types show only irregular areas traversed by numerous cracks and fissures. For the most part such areas show advanced divitrification, so that in the present form they resemble mottled patches with irregular boundaries. Under the high power of the microscope such areas resolve into an aggregate of quartz and feldspar. In cases where devitrification has not progressed too far characteristic glassy textures are still to be seen.

Tuffs

Only a small number of types belong to this group and each is designated according to the kind of lava fragments it contains. As a whole these rocks do not possess great petrographical interest. In the hand specimen they are not conspicuously fragmental, but if examined with a pocket lens they will be found to contain lighter and darker colored grains imbedded in a gray ground mass. Numerous small specks of magnetite are present. The following types seem to deserve mention:

Andesite Tuff.—The andesite tuff includes all the rocks composed of

volcanic detritus which is clearly andesitic in composition. The texture is therefore of wide range and includes rocks made up of lapilli as well as those consisting of sand and dust. Under the microscope the clastic character of the rock is easily recognized and the mass is seen to be composed of intermingled fragments of feldspars and glass. The andesite tuffs are badly altered or decomposed and this feature renders them very difficult to study. Although the alteration is well advanced and the particles are very fine, yet the microscope shows traces of porosity. Many of the fragments still show evidence of original glassy texture. The tuffs alter to kaolin and sericite, and where the ferro-magnesian minerals have been prominent these have given rise to considerable amounts of chlorite and iron oxide.

Rhyolite Tuff.—In the essential features the rhyolite tuff does not differ markedly from the andesitic variety except in the presence of quartz phenocrysts imbedded in a large amount of dust-like material. This dust may have been in part glassy, but the present metamorphosed condition of the products makes any trustworthy statement of the original condition uncertain. The range in size of fragments is variable. Rarely do the particles exceed 5 mm. in diameter and three-quarters of the entire mass is less than 1 mm. in diameter. The presence of quartz grains makes the identification of the rock comparatively easy. This rock involves glassy fragments as well as mineral grains, all of which are sharp, angular particles, exactly analogous to volcanic detritus. Although the macroscopic evidence indicating that the rock is tuffaceous is strong the microscopic evidence is still stronger and demonstrates completely its volcanic origin. Numerous stringers of partly devitrified glass are to be seen, together with numerous small grains of magnetite. Like the andesite tuffs, these rocks are also porous, and when altered give rise to sericite, kaolin, and some leucoxene. The kaolin occurs as irregular earthy patches and in some slides makes up a large part of the rock mass. The sericite had its origin in the feldspars and usually occurs as fine aggregates.

The tuffs as a whole are mineralized and this phase will be described in detail on a later page.

Eleven specimens out of the 24 are fragmental in character and were originally composed entirely of volcanic detritus. They are the tuffs. The fragments vary in size from 3 mm. down to fine dust. Two specimens of the 11 are best classified as andesite tuff, while the remaining ones are decidedly rhyolitic in general make-up. Nine of the 11 specimens show pyrite in varying amounts from fine sprinklings of dust-like particles, not exceeding 3 per cent. of the mass, to those in which the sulphide runs as high as 20 per cent. or more. One specimen shows blende in minor amounts. Seven show the presence of chlorite and serpentine, while two show notable amounts of carbonate. Seven show the presence of gypsum and all show traces of silicification.

Of the tuffs there is one specimen that deserves special comment since it shows some interesting features not commonly seen in the rest but which are believed to be general throughout the entire class of tuffs. This particular feature is to be noted when the sulphate encroaches upon and entirely replaces the quartz grains, Fig. 7. In the same section pyrite is seen encroaching upon quartz grains and completely replacing them. It appears from these slides that the conditions under which the solutions existed were such that silica was dissolved and a sulphide as well as a

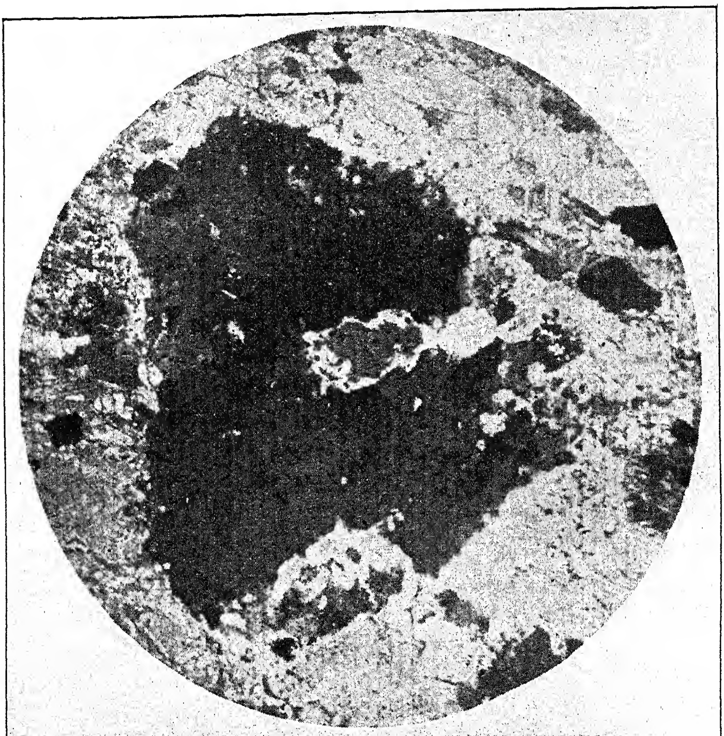

FIG. 7.—DARK AREA IS A QUARTZ GRAIN IN RHYOLITE TUFF.
The quartz is being replaced by gypsum, shown in the upper right-hand area × 50 diameters.

sulphate was deposited. It is well known[8] that the solubility of gypsum decreases with increase of temperature above 100° C., and that silica is dissolved with increase of temperature. It is quite possible that the limits for the solubility of gypsum were closely approached, so that the sulphate already in solution was thrown out and silica taken up. Clarke[9] states that "Hot waters, charged with sulphuric or hydrochloric acid,

[8] Seidell: *Solubilities of Inorganic and Organic Substances* (New York, 1911).
[9] *Bulletin No.* 491, *U. S. Geological Survey*, p. 459 (1911).

attack nearly all eruptive rocks, dissolve nearly all bases, and leave behind, in many cases, mere skeletons of silica."

Two specimens of the 24 are typical breccias, the fragments of which are angular in character, greenish in color and cemented together with gypsum. These rocks are of such unusual petrographic character that they well merit special description. The fragments, although originally sharply angular, are now conspicuously sheared and at first sight resemble

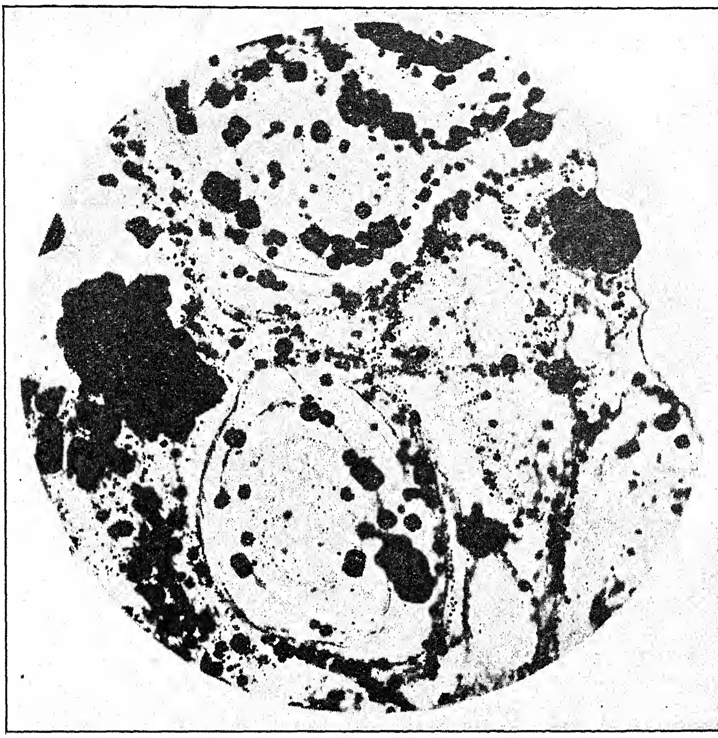

FIG. 8.—THIN SECTION OF A GREENISH FRAGMENT FOUND IN GYPSUM.

The curved lines, accentuated in part by the arrangement of the black sulphide grains, are interpreted to be perlitic cracks of a glassy rock. × 50 diameters. Transmitted light.

pieces of serpentine. They are usually very soft and at times are fissured with carbonate and sulphate of lime.

Scattered through many of the other specimens are greenish areas which closely resemble the fragments of the breccia in hand specimen, but a study of thin sections shows that the fragments of the breccia were originally glassy. In spite of the degree of shearing that is in evidence in most of the surrounding rocks, and also in these specimens as well, many

details of their original texture are preserved with a sharpness scarcely to be looked for in rocks which have had such a history.

It is generally agreed that dynamic action is a powerful agent in completely obliterating all such structures, but in this instance it does not appear to hold true. Glassy rocks are known to be more easily attacked than many others and are subject to either alteration or complete destruction, so that preservation of the glassy breccia without apparent loss of its original earmarks and quick-chill characteristics must be regarded as very

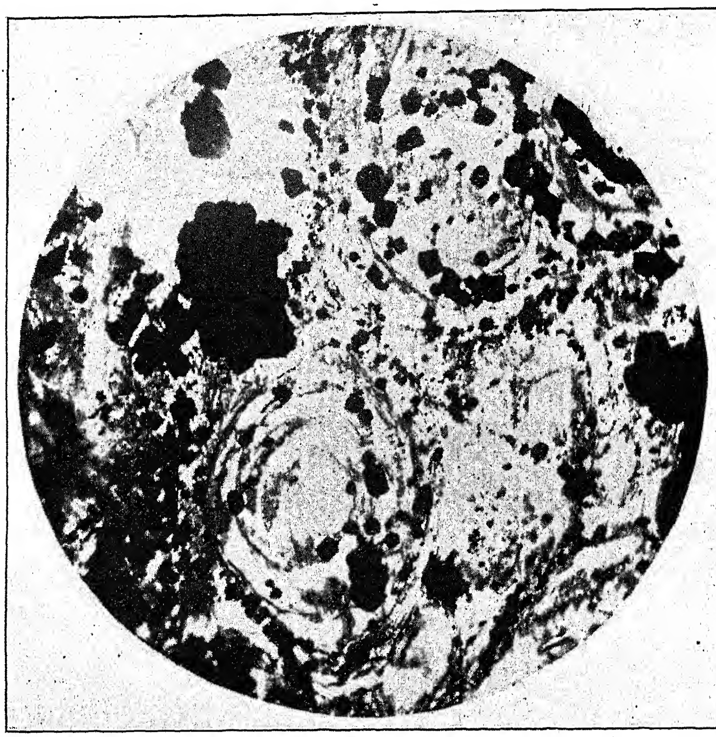

FIG. 9.—SAME SECTION AS FIG. 8, BUT UNDER POLARIZED LIGHT.

interesting, if not exceptional. In the hand specimen the rock presents a uniformly sheared crystalline matrix in which are imbedded greenish fragments varying in size from an inch in diameter downward to microscopic dimensions. Most of the fragments are heavily pyritized and the individual grains of pyrite are conspicuously arranged along curved lines which are exactly analogous to perlitic cracks, Figs. 8 and 9. Many of the fragments show distinct flow lines under the moderate power of the microscope. In the hand specimen they often show how the fragments have been drawn out into "Augen." In some types this arrangement

of the fragments gives to the larger rock masses a distinctly banded appearance.

In thin section the greenish grains are either isotropic or else they show devitrification changes. No chemical analysis of the greenish fragments has been made, but since they are closely related to flow rocks they are provisionally classed as acid glasses. In one thin section the greenish patches show original porphyritic habit. These areas generally represent original glassy rocks and they are certainly being replaced by the gypsum. Stringers and shreds of such material are being encroached upon from all sides, and they remain as cores. Like the breccia, these greenish areas are heavily charged with sulphides, and the conclusion is made that the same mineralizers which introduced the sulphates were influential in introducing the sulphides as well. The sulphate was introduced as a vein filling, and this feature establishes its secondary character. As in the case of the breccia, these rocks were originally flows and are best regarded as acid glasses.

One specimen out of the entire series is classed as a rhyolite flow. It is badly sheared, and under the microscope shows corroded and embayed grains of quartz. Secondary carbonate has replaced some of the ferromagnesian minerals, and this feature gives to the rock a mottled appearance. There are a few patches of divitrified glass which still show pronounced flowage. There is no evidence of introduced sulphate or sulphide. Small amounts of secondary silica are to be seen in microgranular patches.

The remaining specimens are grouped as dikes, and out of the total number of rock types there are eight representatives which can be described under two types.

Under this head are included only those dikes which are intimately related to the ore deposits. There are others in various parts of the area mapped, but they all have a striking similarity in structural relationships. For convenience they will be described in order of age.

Alaskite-Porphyry

This is the most conspicuous dike rock in the district. It is generally light colored, very acid, and is at times mottled. The phenocrysts of the rock consist of quartz and feldspar, the feldspar generally slightly predominating. The ground mass is seen to consist of a microgranular mixture of quartz and feldspar. Some of the larger phenocrysts of feldspar, because of orientation, do not show the usual twinning. The chief accessory minerals are magnetite in small grains apatite, and rarely zircon.

The quartz phenocrysts are embayed and heavily corroded, as seen in Fig. 10. The feldspars are altered in part to kaolin. There is little or no sericite, and the specimen is notably free from mineralization. The rock

mass has been fractured but has been later recemented by quartz. The alteration products are chlorite and epidote in small amount, derived in all probability from original flakes of mica. The dike varies in thickness and on thin edges it is relatively fine grained, while in the center of the larger masses the texture is rather coarsely grained.

Although in places the rock shows conchoidal fracture it contains no glass. Diller[10] regarded this rock as a surface flow and recorded it as being

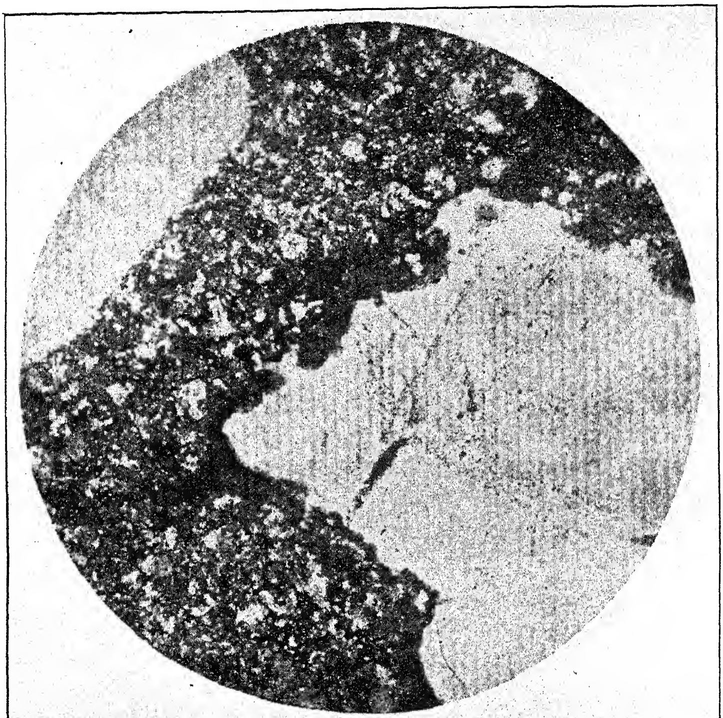

FIG. 10.—CORRODED PHENOCRYST IN ALASKITE-PORPHYRY.
Light area, quartz; dark area, unaltered ground mass. × 50 diameters. Crossed Nicols.

older than the sedimentary formations apparently resting upon it. From his various published statements regarding these relationships it may be inferred that such a conclusion was not reached without some hesitation. Recent study of the structural relations in depth shows that all such masses can best be regarded as intrusives, and this idea was entertained by H. W. Fairbanks.[11]

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[10] *Redding Folio, No.* 138, *U. S. Geological Survey*, p. 8 (1906).
[11] *Eleventh Report of the California State Mineralogist*, p. 32 (1892).

Andesite Dike

In appearance the andesite dike is a dark gray to greenish fine-grained rock, sometimes showing a tendency to amygdaloidal structure. The microscope proves that the rock consists of phenocrysts of orthoclase imbedded in a fine-grained ground mass of lath-shaped feldspars. The chief accessory minerals are magnetite and rarely rutile. The rock appears more basic than is actually the case. It varies in composition from point to point and shows in its northernmost outcrop the presence of some pyroxenes. Like the alaskite dike, it also sends off branches into the country rock, and these are finely felsitic. Both dike rocks have been sheared and have been replaced in part by sulphides, sulphates, and carbonates. Although the dikes vary from point to point the following analyses made on typical specimens of the freshest material will give an idea of their chemical character.

Analyses of Alaskite-Porphyry and Andesite Dike

	(A)	(B)	(C)
SiO_2	78.50	81.25	49.85
Al_2O_3	11.50	9.03	17.00
Fe_2O_3	0.11	0.63	4.02
FeO	1.82	0.40	5.51
MgO	0.46	2.48	7.65
CaO	0.50	trace	1.18
Na_2O	6.04	0.25	4.78
K_2O	none	1.82	none
H_2O at 105°	0.30	1.09	2.16
H_2O above 105°	0.82	2.81	6.65
TiO_2	0.27	0.08	0.97
P_2O_5	0.03	trace	0.10
S	0.13	0.35	0.07
SO_3	none	none	none
CO_2	none	none	none
MnO	0.03	trace	none
BaO	none	0.05	trace
ZrO_2	none	none	none
Totals	100.51	100.24	99.94

(A) and (B), Alaskite-porphyry dike rock near Bully Hill mine, rich in porphyritic quartz. (A) analyzed by George Steiger, (B) by E. T. Allen.

(C), Andesite dike forming the east wall of Bully Hill mine. Analyzed by E. T. Allen. *Bulletin No.* 228, *U. S. Geological Survey*, p. 210 (1904).

The various specimens of the andesite dike show pronounced shear effects and along such planes there is evidence of introduced carbonates

and sulphides. The carbonates fill irregular cavities, and while the sulphide is often found along the borders of the calcite areas it is not confined to these alone. The cracks and fissures are most heavily mineralized, although in one specimen the sulphide appears to be uniformly scattered throughout the mass. In only one specimen of the andesitic dike rock was sulphate found. One specimen shows introduced copper carbonate.

It is in the andesite dike and its apophyses that the greatest amounts of chlorite and serpentine are found. In all cases these products have been produced by hydrous alteration from former ferro-magnesian pyroxenes as well as amphiboles.

More than half of the specimens contain ores, which are confined to the tuffs. Where the gypsum is found it appears also to favor the fragmental rocks, especially the tuffs. In some of the specimens all original structures are obscured in the various processes of sulphatization, sulphidation, and silicification. In a few there are satisfactory evidences of original minerals and structures that prove the tuffaceous character of the original rock. In the rhyolites the phenocrysts have resisted alteration where all other structures have been destroyed. In such cases the ores are essentially replaced rhyolites and rhyolite tuffs. Some of the specimens show marked crushing and these have been preserved as breccias. The sulphides and the sulphates were deposited in some specimens simultaneously, and in others the sulphides alone are promiscuously distributed through the rocks.

V. Description of the Mines

The descriptions are presented according to the geographic position of the three properties in three major groups. The chief producing mines have been divided into the southern, middle, and northern; and comprise the Copper City, the Rising Star, and the Bully Hill, respectively. The writer was permitted personally to visit each of the properties, where ample opportunity was enjoyed for studying both surface and underground geology. Under present conditions such good opportunities are not afforded.

The most southerly of the properties is the Copper City. Although the first property to be extensively worked it is now the smallest. The ore is more difficult to treat than that of the others. The mine is situated about 1,000 ft. west of Zinc creek, and just south of Killanger peak. A tunnel a few feet above the level of Squaw creek has been driven to a distance of 1,000 ft. or more in a northwest direction, and for the greater part of the distance it is in a contact zone between shale on the east and alaskite on the west.

These broad relationships have been modified, however, by extensive fracturing and fissuring, with some shearing, so that while the zone of

mineralization is somewhat irregular, it is roughly northeast in direction and has a nearly vertical dip. The shear zone has been richly mineralized and ore shoots of lenticular shape have resulted. The thickness of these bodies varies from a thin edge on the margins to 14 ft. or more near the middle. The width of the shoots varies from 30 to 150 ft. The central part of the shoot is generally the thickest. The longer axes coincide with the general foliation of the inclosing rocks. Where the walls have been mineralized they have also been mined, but in no instance have they been so productive as to be regarded as important sources of ore.

The principal ore bodies have resulted from the complete replacement of the country rock. The mine is, however, in the early stages of its development, and no very extensive shoot has been mined out. The ore consists of a mixture of pyrite, bornite, chalcopyrite, and an abundance of sphalerite. There are also minor amounts of galena scattered through the masses. In later years the sphalerite has become so abundant as to make the extraction of the copper difficult. The workings have also revealed a badly sheared intrusive dike, containing copper minerals, apparently not original. They are subsequently described.

The next property is about 2 miles to the north of Copper City, and although it is the latest of all to be worked, it is nevertheless of great importance. The mine is called the Rising Star and is situated near the head of Buck gulch, which has its source in the south slope of Bully hill.

The andesites, alaskite-porphyry, and andesitic dike are well exposed. So far as known the andesite dike lies wholly to the east of the principal ore body, and, as already stated, is faulted so that detached portions are shifted to the west. The main lodes are lenticular in shape, with their longer axes pitching 60° or more to the north, and having a general strike of N. 10° E. The shoots have been formed by replacement of the sheared rock.

The ores are mixtures of sulphides, chief of which are pyrite, chalcopyrite, and bornite, with small quantities of sphalerite. Of special interest in this mine are masses of gypsum and anhydrite, with minor amounts of barite, the latter being sparingly present in the ores. The workings are extensive and have reached a depth of approximately 1,000 ft. The surface geology presents rocks which consist almost entirely of sheared andesites and tuffs highly stained with iron oxide. The andesite dike, although not conspicuous, is known to exist to the north and east of the main tunnel. At the time of this writing no commercial ore has been found east of the dike.

The northernmost property comprises the Delamar lode of Bully Hill. This mine is the most extensively developed of all. It is situated on the south slope of Town creek, which has its source in the northeast slope of Bully hill and the southeast slope of Town mountain. The workings are entered by means of a tunnel, Fig. 11, 1,400 ft. long, which passes into

the hill in a general southwest direction. The shaft near the end of the tunnel is more than 1,000 ft. deep and connects with a number of drifts and cross-cuts.

The geology is similar to that of the Rising Star mine. The general structure is simple, but the details of the structure and the deformation which produced it are not only complex but in some instances are beyond exact determination. This is due to the complex folding of the igneous members.

The ore bodies are strikingly lenticular in shape and conform perfectly to the foliation of the sheared country rock. The lodes lie much nearer

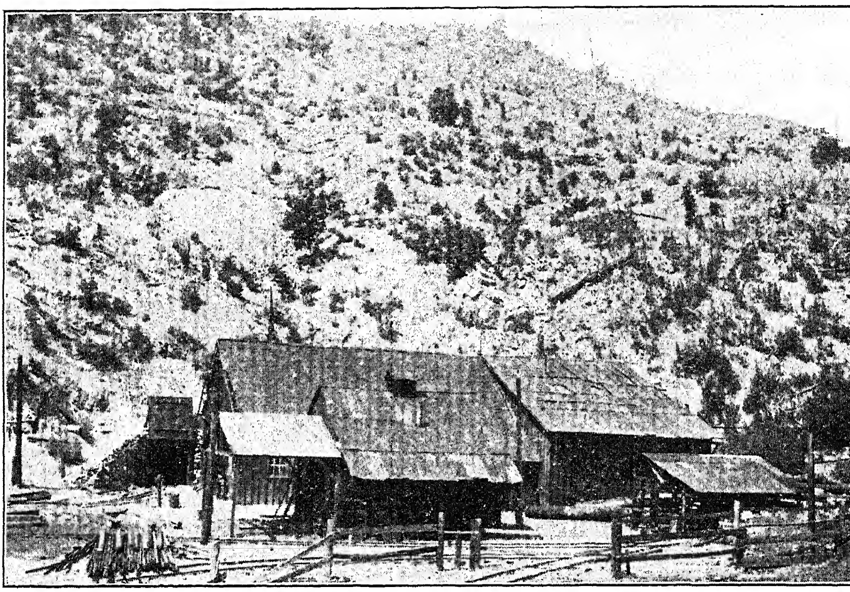

FIG. 11.—THE MAIN PORTAL OF BULLY HILL MINE, LOOKING SOUTHWEST. Alaskite-porphyry seen immediately above the right-hand end of building.

the andesite dike than those in the Rising Star mine. They are richer nearer the dike and leaner as they are followed toward the west. From detailed study there is no doubt that the shoots represent completely replaced sheared rock, which may be andesites, tuffs, or alaskite-porphyry.

The lenticular bodies range in size from masses a few inches in dimensions to those of hundreds of feet in length. The thickness appears to be controlled, in part at least, by the width of the more completely sheared, and therefore the more easily replaced, country rock.

Gypsum and anhydrite occur here substantially in the same way as in the Rising Star mine, and will receive discussion under the topic, "The Gypsum Masses."

Summary.—It is plain from the preceding statements that the mines are located in a line corresponding closely with the shear zone. The shoots are strikingly lenticular in shape, with their longer axes parallel to the foliation of the inclosing rock masses; their longer axes also pitch steeply to the north, and the deposits in places attain a thickness of 30 ft. or more. Additional descriptions of the ore bodies will be given under "Metalliferous Deposits."

VI. Metalliferous Deposits

The metalliferous deposits of the Bully Hill district, so far as known, are simple and uniform, and constitute three principal tracts intimately related to an igneous intrusive (alaskite-porphyry) locally known as Bully Hill quartzite. These tracts are represented on the map and roughly embrace an area of 1 by 3 miles.

The Bully Hill and Rising Star mines form a group comprising the most important ore bodies of the district, and although ore is known at Copper City, and the mines have been operated at irregular intervals for many years, the composition of the ores has until recently made the mine of small importance. Detailed study of the ore bodies shows disconnected but often overlapping masses varying in size from mere flattened nodules several inches in diameter to large masses hundreds of feet in length and 30 ft. or more in width.

These characteristically lenticular masses, which are roughly parallel to the andesite dike previously mentioned, and which lie between it and the alaskite-porphyry, pitch steeply to the north and are longest in that direction. The crushed rock contiguous to the ore bodies and wholly within the shear zone is generally, but not always, impregnated with sulphides. It follows, therefore, that there exist in the mines theoretically two distinct masses of ore, one having a roughly lenticular shape, the other somewhat irregularly replaced brecciated rock. The latter is an important source of ores, and at times is characterized by more or less complete secondary enrichment. It might be stated that while there are two distinct modes of ore occurrence, there is rarely any distinction between the minerals common to both. Occasionally there are residuary cores of rock in the ore which indicate replaced fragments. Aside from this the only distinction is based on sparsely distributed minerals in the country rock.

As the ore bodies lie wholly within a metamorphosed area of igneous rocks, the individual members of which have been sheared and disturbed, it follows that the shoots themselves may likewise be disturbed. Careful study shows that subsequent to the original deposition of the major ore bodies several later dynamic movements have taken place, each producing fractures which have affected the mineral deposits.

Although the movements have for the most part been of the minor order, the subordinate fracturing has taken place mainly parallel to the foliation of the country rock. It is also believed, upon good evidence in the field, that important shifting has resulted at approximately right angles to the existing shear zone. Because of the number and character of the fractures it is impossible to determine definitely the ages of the different movements.

This condition is therefore favorable to the existence of faulted parts of the main ore body, and applies especially to the north end of the Delamar lode in Bully Hill. The evidence—though obscured by the badly sheared country rock, and therefore of rather unsatisfactory character—shows that in all probability the faulted portion can be looked for farther to the east than the main lode in Bully Hill. The strongest evidence bearing on such interpretation is twofold: first, the isolated mass of alaskite-porphyry near the eastern end of Bully Hill dump, which is thought to be shifted from a position which it once had near the main tunnel, eastwardly to its present position; secondly, the brecciated zone and otherwise ground-up material just above the wagon road leading to the Rising Star mine and directly back of the company houses as one goes south. This broken and fractured zone is axially in line with an escarpment produced by an abrupt ending of alaskite-porphyry just west of the main portal. Such brecciated zones, within the mineralized area, have received secondary enrichment by copper-bearing solutions.

In a broad way the general distribution of the productive ore zones with reference to the various rock formations has been indicated in a previous part of this paper. In all cases the deposits occur in or in close association with altered igneous rocks, generally alaskite-porphyry, which because of fracture and partial alteration exhibit various stages of replacement. The occurrence of the ore in depth is indicated on the surface by a reddish, usually porous, iridescent gossan, and is coextensive with it.

When the ore bodies had been finally completed, and when by dynamic movements they were placed above the level of ground water, oxidation resulted and the subsequent production of the gossan began. It is believed that a very great vertical extent of ore was in this manner affected, and it is quite certain that the solutions which leached the surface rocks migrated downward, carrying with them the salts which they could hold in solution, until they came in contact with the reagents which would cause precipitation. It follows, therefore, that the leaner masses below would receive contributions from above and thus become enriched.

The vertical distribution of the ore bodies at present (1913) is known to be 1,000 ft., and at this depth oxidized minerals exist but as compared with upper levels their amount is waning. The downward limit of the copper ores has not been determined.

The areal distribution is shown on the map, but because of the characteristic weathering of the surface rocks, and the subsequent spreading of the gossan, there is no sharp distinction between the country rock and the mineralized rock. In very general terms it might be stated that the Delamar lode can be traced on the surface for a half mile, and the Anchor lode of the Rising Star mine for a quarter mile. The width of the mineralized zone varies, but in round figures it is not far from 300 to 500 ft.

Character of the Ores

In a number of instances pyrite appears to be the chief mineral, with chalcopyrite as a very common and characteristic associate. More rarely, and chiefly in the zones where oxidation and enrichment have been in progress, we find chalcocite, bornite, covellite, and native copper. The typically oxidized ores if followed down to sufficient depth invariably give way to secondary enriched products, and, when these are not prominent, to the unaltered sulphides. Although some grains of metallic copper are found in the superficially changed rock, the decrease in assay values, going downward in the rocks, is doubtless to be explained by the well-known fact that along open, water-bearing, shear and fracture zones, under the action of surface waters, copper minerals suffer rapid alteration and transportation, and only in the uppermost parts of the sheared zone, especially where reducing agents have had play, do we find grains of metallic copper.

At present the deposits of commercial value are mainly those which are below the gossan and are confined to that part of the zone where enrichment has taken place. Wherever the products of enrichment are present chalcopyrite, chalcocite, covellite, etc., associated with zinc blende are found.

Some shipping ore in the Bully Hill district carries as much as 6 per cent. of copper, but the smelting ores, which furnish the bulk of the output, range from 3 to 5 per cent. of copper, and a few ounces of the precious metals, mostly silver, to the ton. The ores of the various mines, as well as different parts of the same mine, exhibit a considerable range in tenor. In the outcrop, where the gossan is in great abundance, small nuggets of gold have been found. It is from this source chiefly that gold has been derived for the placers.

There are many surface outcrops which still yield gold after the rock is crushed and panned. It follows, therefore, that the gossan carries higher values in gold than the ore extracted at depth.

Mineralogy of the Ores

Metallic Minerals (Metals).—Filaments of native copper occur in greatly altered and much-bleached country rock, detailed study of which

indicates that originally the masses were rhyolites or rhyolite breccias. The surface rocks by early mining methods yielded notable amounts of native copper, but at present such materials are not an important source of the metal. Just how the copper accumulated is not known, but in all probability the presence of organic compounds played an important part in its reduction.

Practically all the gold obtained by hydraulic mining occurs in the native state. Although the particles are uniformly small they are usually visible on close inspection in all the detrital accumulations.

In the oxidized ore the gold occurs in a siliceous, limonitic matrix, which, without doubt, contributed to the placers of local areas. From the intimate relation of the gold with the gossan it is evident that a very close association exists between it and the original sulphur-bearing minerals. In the pyrites, however, the gold is in such a state of fine subdivision and is present in such small quantity that it has not been recognized under the microscope. While most of the gangue runs high in iron oxide, the gold is frequently closely associated with cryptocrystalline quartz. In the mine workings, and particularly in the vicinity of the basic dike, there appears to be a genetic relation and close association with barite and sulphides in which the gold is apportioned evenly through the mass. On the surface this mass alters to limonite, quartz, barite, kaolinite, and in a few places to hematite.

Native silver of delicate filiform and more solid shapes has been reported from the upper levels of the mine workings. It is commonly associated with the gold in the iron-stained capping rock, and occasionally with minute quantities of malachite and azurite. The largest and richest masses are found wholly within the oxidized zone quite near the surface. It decreases with depth and is generally accompanied by an increase in zinc and galena, minerals which seriously interfered with the early amalgamation methods adopted at Copper City. It may be stated that in general the occurrence of silver is less common than native copper.

Microscopic Characters of the Ores.—The material for microscopic examination was collected for the purpose of establishing the sequence of ore deposition. In order to study these problems, a series of selected specimens were polished and examined by reflected light, the general procedure following that of the recent researches of Prof. William Campbell and others.

The chief opaque minerals of interest which enter into the composition of the ores of the Bully Hill mining district are, in order of their importance, pyrite, chalcopyrite, blende, bornite, galena, and covellite, with minor amounts of chalcocite. Not infrequently transparent minerals also are present in the specimens, chief of which are quartz, calcite, and gypsum. These minerals, because of the close resemblance to each other

when observed by this method, are best identified in sliced sections rather than by reflected light.

Pyrite.—Detailed studies show that in the freshest specimens of alaskite-porphyry there are no metallic sulphides which crystallized from fusion as did the other components constituting the rock mass. Pyrite is indeed found disseminated through the alaskite, but it is believed that it was formed at a time after the alaskite had solidified. In this occurrence the mineral usually forms aggregates and grains. Individual crystals of free growth and sufficiently large for recognition of the crystal

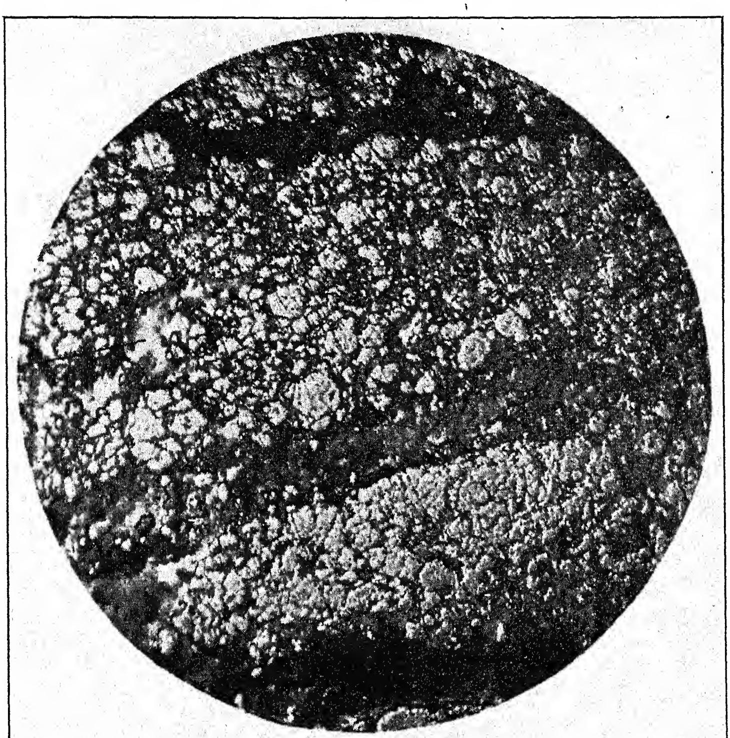

FIG. 12.—LEAN PYRITE ORE WITH VEINS OF CHALCOPYRITE. Reflected light. × 50 diameters.

habit are comparatively rare. Such faces as are visible indicate that the prevalent form is the pyritohedron, variously modified. When the crystals have been able to grow without mutual interference, which frequently happens in places filled with soft massive gypsum or kaolinite, the usual form assumed is a sharply defined cube, in some instances modified by octohedral and dodecahedral faces. Such forms have been noted particularly in the Delamar lode of Bully Hill. Some brilliant crystals have been found imbedded in a quartzose matrix just to the north of Bagster

shaft. These studies show that pyrite was the first of the ore minerals to crystallize. Whether or not the pyrite is auriferous is not easily determined. That it is not highly so is certain, since tests of the most pyritous matter often show little or no gold, and an abundance of pyrite is generally a sign of poor rather than of rich ore.

Where the pyrite is in masses innumerable branching cracks traverse the specimen in every direction (Fig. 12). As far as could be determined, no other metallic mineral of importance could be seen. This fact does

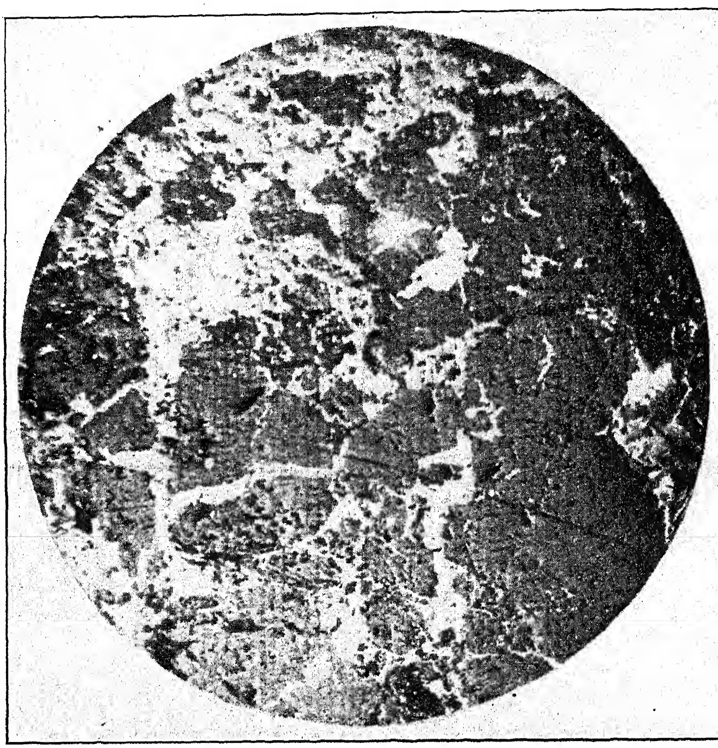

FIG. 13.—BRECCIATED COUNTRY ROCK.
Filling material chalcopyrite. Reflected light. × 50 diameters.

not fully coincide with the results of chemical investigation, because it is almost impossible to select any sample of lean pyrite that will not give traces of copper. Whether the pyrite contains minute grains of a copper mineral as a mechanical inclusion, or whether the pyrite is a lean chemical compound of copper and iron, could not be determined by this method of reflected light. Aside from the chemical tests the pyrite appears to be pure, and its deposition for convenience has been designated as the pyrite phase.

Chalcopyrite.—The second stage of ore deposition is apparently

characterized by the introduction of chalcopyrite (Fig. 13). This primary mineral closely followed pyrite, although in rare instances, as stated by L. C. Graton,[12] "small grains of chalcopyrite. . . are inclosed in the pyrite individuals." Studies made by the writer point to the conclusion that chalcopyrite has been the last mineral to enter. This mineral completely surrounds the pyrite grains and in some instances enters the minutest fissures of the partly crushed pyrite masses. At times the pyrite and the chalcopyrite are so inextricably mingled that their physical appearances are almost identical, and it becomes difficult if not impossible to distinguish, in the hand specimen, one mineral from the other. In such cases simultaneous deposition may be employed to explain these complex relationships, although from the examination of many specimens the evidence indicates chalcopyrite as being later than the pyrite.

Sphalerite.—Like pyrite and chalcopyrite, sphalerite is one of the primary minerals and is everywhere crystalline. Sphalerite is later than pyrite and is seen to surround particles of this mineral. Unlike the pyrite with which it is so intimately related, it does not form well-bounded crystals even where conditions of free growth appear to have been favorable. The blende is so common throughout some of the ores, especially those near Copper City, that a zinc-extraction plant is now being constructed for its recovery. Near the surface it is easily oxidized, and, aside from a few occurrences, its products appear as sulphates on the walls of the mine workings.

Bornite.—The isometric sulphide of copper (peacock copper ore, Cu_5FeS_4), though moderately abundant as a secondary mineral, is very sparingly found in the primary ore of the district. It is always massive with a recognizable crystalline structure, and is generally met in forms irregularly rounded, closely related to the other sulphides In no instance is it entirely isolated, but according to microscopic study it is intimately associated with pyrite and chalcopyrite, and in some cases clearly shows close association with sphalerite.

Galena.—Primary sulphide of lead occurs sparingly in the copper ores of the Bully Hill district. It is rarely isolated, but occasionally it is found sparsely disseminated through country rock at the Bagster shaft. It occurs in massive form, both cleavable and granular, rarely crystalline and never crystallized. It is not widespread in any of the mines studied and is found intimately associated with primary chalcopyrite, pyrite, and blende. It has been noted especially in the high-grade sulphide ores of the Delamar lode (Fig. 14) with the other sulphides. It does not occur, so far as known, in the workings of the Copper City or Rising Star mines. Since galena is rarely encountered in depth its alteration products

[12] *Bulletin No.* 430, *U. S. Geological Survey*, p. 103 (1910).

on the surface were not observed. It is quite probable that the galena as well as the blende is argentiferous, and that would explain the presence of high silver values in the gossan as well as in the regular mine-run of ore. It is plain from a detailed study of the relationships of the minerals that galena favors rich sulphides, especially where blende is in large amount.

Chalcocite.—The cuprous sulphide is not a common mineral in any of the ores of the district. It occurs as dotted masses intimately associated with bornite. Mr. Graton[13] states that chalcocite and bornite apparently

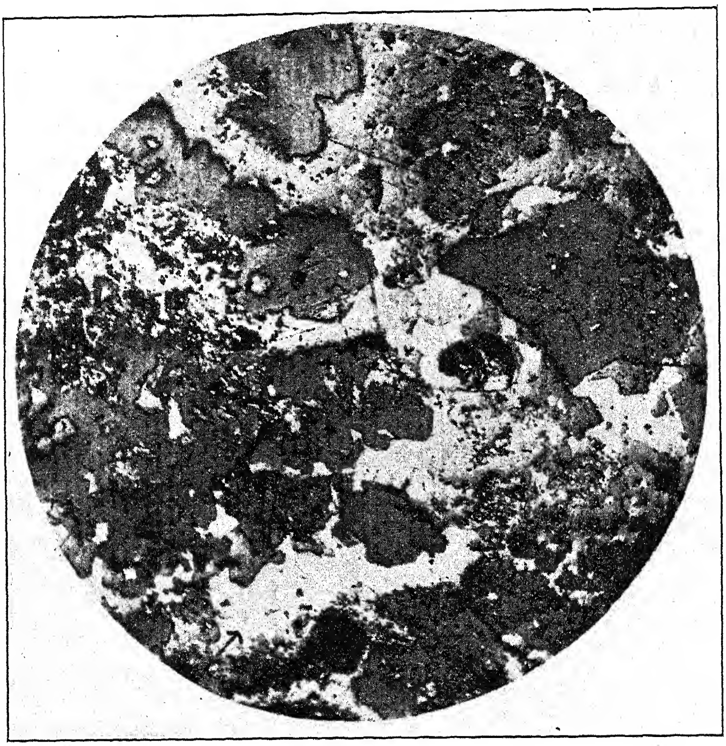

FIG. 14.—RICH COPPER ORE.

White areas, galena; darker, bornite and chalcopyrite; black, quartz. Reflected light. × 50 diameters.

take the place of chalcopyrite as an irregular network through and around the other sulphides. Chalcocite was found in small amounts in the deepest workings of the Bully Hill mine and has been regarded by Graton[14] as primary as well as secondary. From recent studies made by the writer, although not rigidly limited, it is generally confined to the upper levels in close association with other enriched sulphides.

[13] *Bulletin No.* 430, *U. S. Geological Survey*, p. 104 (1910).

[14] *Idem*, p. 105.

Secondary Enrichment

The oxidized zone in the Bully Hill district continues, in general, to unusual depths. The lower limit is known to be as low as the 1,000-ft. level. The ore in this zone is considerably enriched, and the enrichment was materially favored by the openness of the mass because of the abundance and relative size of the cracks and fissures, these being possible only in materials which are brittle, such as quartz and pyrite.

The profound modification resulted chiefly through the action of descending waters which in their downward course traversed zones in which small but important amounts of copper-bearing sulphides existed. The following equation illustrates the probable chemical reaction:

$$CuSO_4 + 2\,FeS = CuFeS_2 + FeSO_4.$$

As an illustration of the principles of ore deposition, or, rather, ore concentration, this chemical reaction can hardly be overestimated, and since the conditions assume the presence of copper minerals near the surface, this phenomenon is usually related to the second concentration. The first is believed to have been brought about chiefly through the action of ascending hot waters, while the second concentration is almost exclusively related to cool descending waters. It follows from this that if the concentration processes be regarded as cycles the first is far the more important, and as suggested was directly related to the intrusion of the acidic (alaskite) dike. Copper-bearing rock which probably contained less than 1 per cent. of copper will now show from 6 to 8 per cent. in the oxidized zone. Where the replacement has been complete more or less calcite, quartz, and barite are found. It should be stated, however, that while barite has been found in the ores it is not at all important. J. S. Diller[15] regards the barite as a primary constituent of the ores. Calcite and quartz are wholly secondary and occur more or less abundantly at all levels of the various mines.

In most cases observed the mineral relations are fairly definite and leave little room for question. In other relations there is room for more than one inference. The order given is believed to be correct in the main. The disturbing element in most instances is alteration. In no specimen is there any suggestion of a distinctive silver mineral, although the ores yield several ounces to the ton. The presence of other sulphides, notably arsenic and antimony, was not detected. The enriched sulphides taken from the deepest levels of the mines are indicative that the lower limit of descending circulating ground water has not been reached, and therefore that the zone of lean sulphides has not been entered.

One other mineral of great importance and intimately associated with

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[15] *Redding Folio, No.* 138, *U. S. Geological Survey,* p. 12 (1906).

the ores, especially of the Bully Hill and Rising Star mines, is the hydrated sulphate of calcium, gypsum. L. C. Graton[16] reports anhydrite as well, but so far, the examination of many slides has not revealed its presence extensively. The explanation advanced for the gypsum will also account for the anhydrite, and this will be given in "The Gypsum Masses."

Genesis of the Deposits

The preceding pages set forth the problems awaiting solution, and only a brief recapitulation is deemed necessary of some of the most significant facts with which an adequate explanation of the ore genesis must harmonize.

The association of the ore deposits with the intrusives is interesting, and a study of the lean ores is one that promises to give most light on their origin. Due consideration must also be given to the mechanical alteration and subsequent changes wrought in the dike materials through which suitable solutions passed, and by which the concentration and enrichment of the ore bodies were made possible.

The fissures produced a weakened zone which not only permitted the solutions to circulate, but determined also the place where the intrusives (dikes) should pass. While it is believed that chemical alteration has facilitated important surface changes, the larger structures of the rock masses in depth are believed to have been caused primarily by deep-seated agents. As far as the andesite flows are concerned, detailed study shows that they were originally almost entirely free from all sulphides.

The limits of the belt which suffered shear in the area mapped are not definitely known, but from data at hand it appears that a strip which measures 1,000 ft. or more in width and several miles in length, at least, has been affected. This zone, which deviates locally, trends practically north and south over long stretches, and it is characterized from point to point not only by variation in width, but also by the degree of mashing and shearing.

A feature of economic significance and one that should receive attention is the fact that the greatest brecciated and comminuted section is not symmetrically located with reference to the side limits of the shear zone; but is decidedly to the eastern border of the belt. Thus in passing across the outcrop of the belt the first few hundred feet encountered closely resemble schists, while toward the west the degree of schistosity becomes less and less until finally the rock masses on the opposite border are practically free from such induced structures.

Another feature which is very conspicuous, especially in Bully hill, shows that locally there are at least three shear zones comprised within the belt. Together they embrace a total width from east to west of approxi-

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[16] *Bulletin No.* 430, *U. S. Geological Survey,* p. 100 (1910).

mately 1,000 ft. They are seen in Fig. 6, looking northward, as a series of ridges in the profile of the hill. The eastern zone incloses the alaskite dike and contains the Delamar lode of Bully Hill.

The rough, rugged ridges are forms which have resisted erosion more effectively than the surrounding materials. With the exception to be noted, all such ridges are referable to silicified sheared rock, chiefly andesite flows and tuffs. It appears that the materials are mainly tuffaceous, of rather wide range with regard to fineness of grain; and it is believed that such materials, because of their porous character, permitted siliceous waters to circulate more freely than the more massive andesite flows. The solutions came from below and are believed to have transferred silica, which was derived from silicate minerals in the deeper parts of the crushed zone, to its present position. Weathering has also influenced the composition of such materials by dissolving out soluble constituents, so that in some areas the mass is rather porous.

The exception referred to above is found in the disconnected masses of alaskite-porphyry. This material, because of its position and external physical appearance, closely resembles the masses in the shear zones. Close inspection, however, shows the latter to contain small phenocrysts of quartz, while the former contains only secondary quartz. In some instances, especially where shearing has been excessive, and the rock is badly stained by iron oxide, identification can be established only by microscopic study. In the field the alaskite is often mottled with darker patches, and in most instances the rock breaks with conchoidal fracture. These serve as a guide, for such earmarks are never seen in the materials of the shear zone.

Attention will be directed first to relationships, and in this connection they will be described as a unit and will embrace the following elements: (1) what relation exists between the rhyolites and the copper ores; (2) between the alaskite and the copper ores; (3) between the andesite dike and the copper ores; (4) and lastly, between all these and the gypsum masses?

(1) The most important changes in the rhyolites previous to mineralization are those referable to mechanical alterations. The rock masses where brittle were broken and a zone of weakness was formed. After long-continued fracturing the intrusion of alaskite-porphyry followed the weakened zone and was accompanied by magmatic emanations which passed along the borders of the intrusive and were otherwise limited to the zone of mashing. These solutions were hot, especially rich in CO_2 at the beginning, and later they carried ore-bearing and silica compounds. It is believed also that these richly carbonated waters as they passed through the various limy strata dissolved large amounts of lime and transported it to the zone where vigorous shattering had taken place. This seems in accord with the facts, as the veins or fissures are chiefly filled with a mix-

ture of calcite inclosing minor amounts of chalcopyrite and pyrite. The fissured rhyolites were thus cemented by these minerals.

(2) Long before the alaskite had completely solidified stresses again became operative, this time breaking the alaskite-porphyry and also disturbing the andesites. Mineralization and impregnation of this rock by metallic sulphides resulted. It is therefore logical to make the statement that this is the first stage in the genesis of the copper ores. Accompanying this change, although not definitely connected with the deposition of the ores, was more or less sericitization, silicification, etc., in the rock masses.

The brecciation forces which acted on the alaskite-porphyry finally produced essentially the same shear planes that were observed in the inclosing andesites, so that both rock types behaved practically as a structural unit to all later phenomena. These were important stages in decomposing the constituent minerals, and they were followed by chemical modifications which were later represented by completely altered rock masses and the production of secondary silicates.

(3) Shortly after the production of the foliated structures igneous activity was again characterized by the intrusion of an andesite dike, which also followed the foliation planes, and in places cut across the alaskite-porphyry by intruding into the shear planes developed in its mass. Of all the rocks in the Bully Hill district this andesite dike was the last to appear and it closely followed the alaskite-porphyry. Outside the area mapped an intrusive rock, in composition more basic than those described, is known. From these relationships it is believed that each fraction from the original magma became progressively more and more basic, and that accompanying the last intrusion magmatic solutions rich in calcite and barite, together with metalliferous compounds, were also given off and reached the sheared zones. These solutions started out hot and in their upward journey they received heat and chemical energy from the dikes which had intruded the rocks and had not cooled entirely. They were thus effective agents and at once attacked the rocks which were most crushed and comminuted. The andesite dike in places was thus encroached upon by the carbonated compounds, and frequently entirely replaced.

Since the andesite dike is partly mineralized it follows that some of the economic minerals were deposited after the intrusion of the alaskite-porphyry. It is necessary in treating the genesis of the ores to account for the copper minerals in the alaskite. The most reasonable and logical explanation is that they were transferred by the agency of highly heated solutions. That some of the solutions contained lime is certain, because in the andesite dike numerous cavities filled with calcite exist.

Copper compounds in underground highly heated solutions are doubtless carried in many forms, probably more as acid compounds. Assuming

that pressure and temperature are important factors at depth, a decrease in either of these might furnish conditions under which deposition would take place. Whatever the chemical nature of the solutions that transported the metallic sulphides, it is certain that they were deposited in the sheared alaskite-porphyry mass.

The magmatic solutions that followed the andesite dike contributed additional metallic sulphides, chief of which were blende, bornite, and galena. Important amounts of chalcopyrite were also introduced which greatly added to the richness of the ores. It should be stated that in all stages of mineralization the sheared rocks were impregnated indiscriminately. The element of control seems to have been the sheared zone. In several places the andesite dike is partly mineralized, but so far as known the ores appear only as a thin crust or veneer on the dike rock.

Several diamond-drill holes were driven through the andesite dike to ascertain conditions on the opposite side. No ores were found, and so far as known only the hanging-wall side of the dike contains sulphides. In the opinion of the writer the opposite side of the dike rock should be prospected, although it is quite possible that the position of the dike partly influenced the course of the solutions in such a way as to leave the rocks on the other side practically barren. So far, marketable ores have been found only on the west side of the dike.

It is not believed that there were open spaces in the rocks sufficiently extensive to account for the ores as they now appear. A characteristic of many thin sections is compactness rather than porosity, although the porous nature of the tuffs would be adequate to explain ease of circulation in any direction. The interpretation of the available evidence strongly supports the hypothesis of partial to complete replacement, and the facts upon which this view is based may be summarized as follows:

(1) The lodes preserve structures, especially schistosity, which exist in the country rock.

(2) Inclosed masses of partly replaced remnants of the original crush-breccia exist as cores.

(3) In all the ore associations, there is clearly to be seen a gradual transition from rich through lean ore to barren country rock.

The elements involved in the explanation are consistent with the facts and the hypothesis of replacement molecule by molecule of the rock masses by the ores seems to be justified.

In connection with the process of replacement, it is of interest to note how a very acid rock like alaskite, and for that matter the andesites as well, could be partly if not wholly replaced. It has been mentioned that the magmatic waters carried carbon dioxide and that lime was dissolved from strata through which such waters passed. Carbonated waters, as

pointed out by Clarke,[17] are solvents for most of the common minerals, including quartz. It is believed that some of the solutions, thus carbonated, in passing through the disturbed zone attacked the acid as well as the basic rocks and left in most instances only the resistant minerals. Carbonate was in this way introduced, as shown in Fig. 15. It was accompanied in some instances by notable amounts of chalcopyrite.

Simultaneously with the introduction of carbonate, mineral hydration and removal went on, and in some rocks, especially the dike, considerable

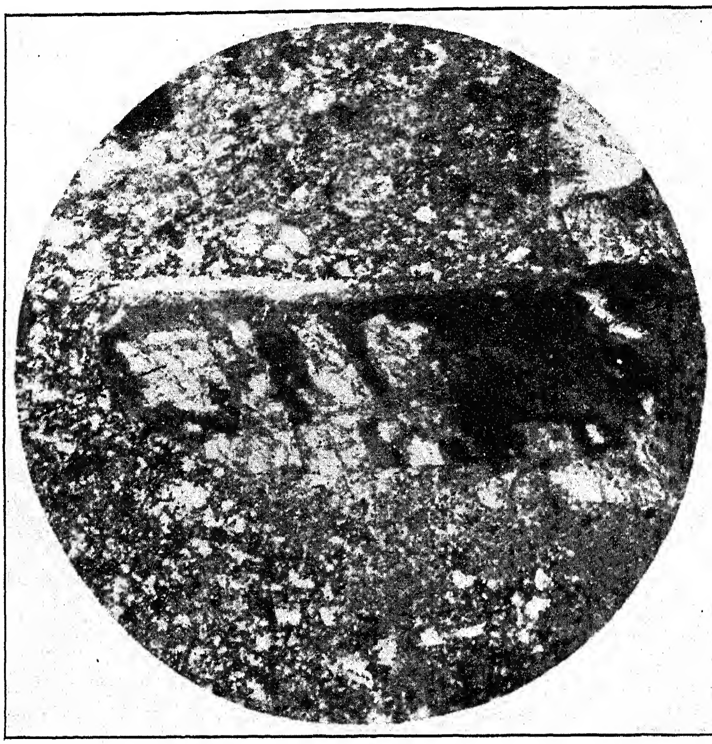

Fig. 15.—Feldspar in Andesite-Porphyry being Replaced by Calcite. The felty areas are unaltered ground mass. × 50 diameters. Crossed Nicols.

chlorite was formed. The quartz grains of the alaskite-porphyry were corroded, and in some instances at least were completely removed. The removal of quartz is believed to have taken place through the influence of the alkaline solutions. This phase of the subject will receive detailed discussion under a later heading.

(4) The concordant testimony of a great variety of evidence from a large number of slides suggests several important phases of mineralization

[17] *Bulletin No.* 491, *U. S. Geological Survey,* p. 457 (1911).

processes. The study shows that there was a certain definite order or sequence of deposition, although these relations are partly obscured by the deposition of some compounds which began with the earliest stages and continued persistently through the entire process to the last stage. Such minerals as pyrite and quartz are the most important representatives of this class.

The important phases are those genetically related to carbonatization and sulphatization. From a study of thin sections, the former was a process by itself, while the latter included pyritization in addition to sulphatization.

The presence of certain minerals and their various mutual relationships suggest a common source, and also that the source was rich in the elements which form the compounds now found in the rocks. Carbonates, sulphates, and sulphides are seen in nearly every slide in varying amounts.

The most important geological factor which assisted the circulating solutions was undoubtedly the sheared structure of the rock masses. The solvent power of the solutions, under high temperature and pressure, was very great. The ferro-magnesian minerals were the first to be completely altered, and these changed chiefly to chlorite. The feldspars apparently were the next to yield, and alteration has gone on so completely that in most cases very little remains to suggest their former presence. In some of the ore samples grains of quartz, supposed to be the original phenocrysts, still remain, but these are usually badly corroded. Their relations to the ores are shown in Fig. 14.

VII. The Sulphate Deposits

In the following descriptions of the various types of sulphates, the rocks will be considered in order of their abundance as they have been found in the mine workings up to the time of the writing of this paper. Whether these relationships as they now exist will continue in depth is a matter on which we have no absolute data, and about which we can only speculate.

The sulphates constitute rocks of considerable importance in the mines of this district. Their existence on the surface with the exception of barite is unknown, and their extent in the working places, although conspicuous, is not usually well defined. The occurrence of sulphates underground is not limited to the upper oxidized zone, but these compounds are known to extend as low as the 1,000-ft. level (the lowest point reached in a shaft in 1912). Although, as previously stated, there are indefinite areal and vertical limits to the occurrence of the various sulphates, still there are fragmentary relationships existing between these compounds and the rocks which serve as a working basis for interpretation. The principal sulphates are gypsum, anhydrite, and barite.

Gypsum

The monoclinic hydrous calcium sulphate ($CaSO_42H_2O$) is first noticed in the mine workings near the 300-ft. level and from this point it continues downward to the lowest levels of the mine. It is usually of a light gray color, massive to banded, and rarely found in crystals. Its banded appearance is not due to any variation in its composition but is produced by inclusions of other rocks, the fragments of which have been arranged by shearing processes into roughly parallel positions.

At some points it is found in larger masses in a comparatively pure state, but the greater amount in the drifts and tunnels is streaked and locally contains pyrite. The larger masses are soft, usually white and everywhere crystalline. At times the pure fragments are translucent, and it is possible to secure masses several feet in dimensions. Where the rock is in such large masses it is very difficult to mine because of its soft character and its resistance to the action of explosives. For this reason, and also because of the expense of drifting through it, the limits of such masses are not known. Drifts in such bodies are characterized by being noticeably dry.

It is of interest to note that the gypsum as a whole is found limited to the shear zone in depth, and thus far has not been reported from any point on the surface. It is found only in the richest mines, intimately associated with the sheared rocks. In a general way it is seen in the hand specimen to surround masses and fragments of many of the rocks which enter into the structure of the hill.

Anhydrite

The anhydrous calcium sulphate, anhydrite ($CaSO_4$), is found in the rocks in very close association with gypsum. Like gypsum, it has never been found on the surface. In the fresh state it is marble-like in texture and varies in color from a dull white to various shades of light blue. It is never translucent, and is easily distinguished from gypsum in being harder and in having a pseudo-cubic cleavage in which the planes are perpendicular to each other, but of a somewhat differing degree of perfection. It is less abundant than gypsum and optically differs from it in having moderate relief and high double refraction. The rectangular cleavage is also marked. In thin section it is seen to have practically the same relationships as the gypsum.

Barite

Barite, the orthorhombic sulphate of barium, $BaSO_4$, occurs only sparingly in the mines of the district. It is a heavy light-colored mineral

having vitreous luster. This mineral is the only sulphate found on the surface and is usually detected by its glistening crystal faces and the relatively great weight. According to Diller[18] the barium had its source in the feldspars of the alaskite-porphyry. After a number of careful tests the writer was unable to detect any barium in the feldspars of this dike rock. It is believed that the barium which furnished the barite had its origin in the same source which supplied the sulphides. Since this mineral is so sparingly present it will not receive further discussion.

Origin of the Deposits, with Special Reference to Gypsum

Before proceeding to a discussion of this subject a summary of the relationships of the gypsum is given. An effort has been made to bring together all the data bearing directly on the problem and also to condense, as far as possible, the descriptions of numerous slides examined The statements represent facts gathered from the field as well as from detailed microscopic study. A few of the most important relationships are given below:

Field occurrences of gypsum:

1. It is found only in the greatest shear zones.
2. It is never found on the surface in the vicinity of the mines.
3. It begins on the 300-ft. level of the mine and extends to the lowest (1,000-ft.) level.
4. It does not occur outside the zone affected by shear.

Microscopic relations:

1. It replaces quartz grains and glass fragments.
2. It occurs as fissure fillings.
3. It is an alteration product after anhydrite.
4. It completely surrounds rock fragments.
5. It is intimately associated with the sulphides.

In order to explain the conditions given and to account for the origin of the gypsum in this deposit, it will be well first to outline the different theories advanced for the accumulation of gypsum the world over. These are: First, deposition from sea water. Second, deposition through volcanic agencies. Third, deposition by thermal springs. Fourth, deposition through the action of sulphuric acid, derived from pyrites, upon the carbonate of lime. Fifth, Hunt's[19] chemical theory of gypsum formation. This theory is somewhat complex, but Hunt believed it applied to a large part of the gypsum of marine and fresh-water origin. This theory does not apply in this case.

Applying these criteria to the deposit in this district we find that the

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[18] *Redding Folio, No.* 138, *U. S. Geological Survey,* p. 12 (1906).

[19] *Quarterly Journal of the Geological Society,* vol. xvi, p. 154 (1860); *Chemical and Geological Essays,* pp. 80 to 92 (1874).

mode of formation as set forth by the first and fifth theories is not applicable. The second and fourth only demand careful consideration, and for convenience of discussion will be taken up in the reverse order.

Deposition through the Action of Pyrites upon Carbonate of Lime.— This method is perfectly possible and has taken place without doubt in an extensive way in nature, but there are certain initial conditions which do not appear in this region. First of all there must be deposits of limestone sufficiently large to form the gypsum deposit as it now appears. That sulphides oxidize to sulphates is well known. If we start with pyrite the final oxidation products are indicated by the following chemical equation:

$$FeS_2 + 7\ O + H_2O = FeSO_4 + H_2SO_4.$$

It is seen that one molecule of pyrite will yield one each of $FeSO_4$ and H_2SO_4. To be on the safe side, it is assumed that both $FeSO_4$ and H_2SO_4 operate to produce sulphate of lime, although it is very doubtful if the ferrous sulphate acts in this manner. The molecular weight of gypsum is 172 while that of pyrite is 120. If these be converted into molecular volumes it is found that for 74.8 volumes of gypsum we require 24 volumes of pyrite, or that for every 100 volumes of gypsum there must be 32 volumes of pyrite, on the basis that H_2SO_4 only goes to make up the sulphate. Under these conditions, and also assuming that the gypsum in territory not yet explored is as thick as that already found, a uniform bed of pyrite approximately 224 ft. thick would be required. If, however, both $FeSO_4$ and H_2SO_4 go to form the sulphate, then one-half of this thickness would suffice. There is no evidence that any such deposit of pyrite ever existed in the district.

By the same method of reasoning it is found that to account for the calcium in the gypsum a bed of carbonate approximately 350 ft. thick would be required. There is no evidence that any such bed of carbonate ever existed in the mine workings. On the other hand, there is distinct proof that clastic volcanic rocks, or their remnants, are the dominant rocks of the district. The failure of this theory to explain the deposits makes it evident that this method of origin could not have been the one to which this deposit owes its existence.

Deposition from Thermal Springs, and through Volcanic Agencies.— These two theories have been grouped as one, since their effects from a geological point of view are very similar. It is well known that emanations from deep-seated cooling igneous magmas are numerous, and, as shown in an important paper by Lincoln,[20] consist of acids, gases, and sublimates.

By referring to the structural section, Fig. 1, it will be seen that a massive limestone (the McCloud) has been involved in the folded and otherwise compressed strata. Since this limy member was in the crush

[20] *Economic Geology*, vol. ii, No. 3, p. 258 (Apr.–May, 1907).

zone through which the emissions of the igneous magma passed, it is perfectly reasonable that the rock would suffer more or less solution by the acid liquid solutions. These may have been in part water containing CO_2, SO_2, SO_3, or SO_4. Any of these alone would dissolve the lime carbonate and transport large amounts to higher points. Whether the lime was carried as carbonate or sulphate or as a mixture of the two is a matter about which we can only speculate. It is possible that certain solutions were chiefly carbonate while others were sulphate in general composition. That both solutions existed is shown by the presence of carbonate as well as sulphate in the rocks, but since sulphate is in largest amount it follows that solutions of this character were dominant.

Whether the sulphate was deposited as anhydrite or as gypsum is not certain, although Graton[21] from his studies concludes that anhydrite is primary and that gypsum is a secondary product derived from anhydrite. There is room for further study on this point because of the well-known fact that gypsum may be transformed into anhydrite,[22] or that the reverse reaction, anhydrite into gypsum, may readily take place. Furthermore, it is known that anhydrite thus formed may be reconverted into gypsum.[23]

The writer is fully aware, however, that within the limits of experiment the solubility of sulphate increases up to about 38° C. and then decreases for additional increments of temperature. This is somewhat against the theory of transportation of sulphate, but there are so many variable factors which tend to offset this decrease in solubility that we are driven to the conclusion that these sulphate deposits have accumulated by the transportation of lime by magmatic solutions from deep-seated sources.

Considering the origin of the gypsum deposit as well as that of the metallic minerals so closely associated with it, this theory seems to accord most satisfactorily with all the fundamental relations and facts brought out by detailed study.

VIII. Summary

From the previous descriptions and discussions, and also from a detailed study of all available data bearing directly upon the deposits of this character, the following general conclusions seem to be warranted:

1. The structure is conspicuously closely crumpled, and where slightly overturned the folds are accompanied by breaks which result in a tendency to develop weak crush and shear zones along the chief planes of movement.

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[21] *Bulletin No.* 430, *U. S. Geological Survey*, p. 100 (1910).

[22] *American Chemical Journal*, vol. xi, p. 31 (1889).

[23] F. Hammerschmidt: *Mineralogische and Petrographische Mittheilungen*, vol. v, p. 272 (1882–83).

2. The copper ores of the Bully Hill district were originally deposited from magmatic solutions in which the metals were transported as soluble sulphides and were deposited as such.
3. From the character of the metallic sulphides, the associated minerals, and the structural relationships, it appears that replacement has been the dominant process in these deposits.
4. The accumulation and concentration of the ores as they are now found involves secondary enrichment, changes in which precipitation by mingling solutions and reactions on wall rock are of greatest importance.
5. The mineralization processes have apparently taken place under conditions which were entirely independent of rock mass control, as tuffs, flows, and dikes, differing widely in physical and chemical make up, are indiscriminately replaced.
6. The lime as calcite, and the sulphate either as anhydrite or gypsum, had an origin in deep-seated sources, and both these minerals were genetically related to the sulphidation process which has given rise to the ores.

IX. Bibliography

Geology of Shasta County, Cal.

Diller, J. S.: *Folio No.* 138, *U. S. Geological Survey* (1906).

Fairbanks, H. W.: Geology and Mineralogy of Shasta County, Cal., *Eleventh Report, California State Mineralogist*, pp. 24–53 (1892).

Notes on Some Localities of Mesozoic and Paleozoic in Shasta County, Cal., *American Geologist*, vol. xiv, pp. 25–31 (1894); Describes geologic structure.

Outline of the Geology of California with Reference to its Mineral Deposits, *Mining and Scientific Press*, vol. lxxiv, pp. 132–232 (1897).

Smith, J. P.: Salient Events in the Geologic History of California, *Science*, N. S., vol. xxx, pp. 346–350 (1909) Outlines the geologic history from the Cambrian to the present.

Ore Deposits of Shasta County, Cal.

Beck, Dr. R.: *The Nature of Ore Deposits.* Translated by W. H. Weed. 487 pp. (New York, 1909).

Diller, J. S.: *Folio No.* 138, *U. S. Geological Survey* (1906).

Fairbanks, H. W.: Geology and Mineralogy of Shasta County, Cal., *Eleventh Report, California State Mineralogist* (1892).

Graton, L. C.: Contributions to Economic Geology, *Bulletin No.* 430, *U. S. Geological Survey*, pp. 71–111 (1910).

Hershey, Oscar H.: Primary Chalcocite in California, *Mining and Scientific Press*, vol. xcvi, pp. 429–430 (1908).

Packard, George A.: Copper Mines and Smelteries of Shasta County, Cal., *Engineering and Mining Journal*, vol. lxxxviii, pp. 393–399 (1909).

Thomas, H. H., and MacAlister, D. A.: *The Geology of Ore Deposits*, pp. 160–161 (London, 1909).

Gypsum

FORMATION OF GYPSUM, *Quarterly Journal of the Geological Society*, vol. v, pp. 172–173, 339; vol. vi, p. xlix (1849, 1850).

HUNT, T. STERRY: On the Origin of Gypsum, *Chemical and Geological Essays*, chap. 8 (1874).

ROSE, H.: On the Solubility of Gypsum, *Poggendorf's Annalen*, vol. xciii, p. 606 (1854).

MARIGNAC, C.: On Solubility of Gypsum, *Annales de Chimie*, 5th ser., vol. i, p. 274 (1874).

McCALEB: On the Solubility of Gypsum, *American Chemical Journal*, vol. xi, p. 31 (1889).

ROGERS, A. F.: The Occurrence of Gypsum and Anhydrite at the Ludwig Mine, Lyon County, Nevada, *Economic Geology*, vol. vii, pp. 185–189 (1912).

SURR, GORDON: Notes on Occurrence, Origin, etc., of Gypsum, *Mining World*, vol xxxiv, pp. 1283–1284 (1911).

HESS, F. L.: A Reconnaissance of the Gypsum Deposits of California, *Bulletin No.* 413, *U. S. Geological Survey* (1910).

Miscellaneous

CLARKE, F. W.: The Data of Geochemistry, *Bulletin No.* 491, *U. S. Geological Survey* (1911).

GEIKIE, JAMES: *Structural and Field Geology* (New York, 1905).

HARKER, ALFRED: *The Natural History of Igneous Rocks* (New York, 1909).

IDDINGS, J. P.: *Igneous Rocks* (New York, 1909).

KEMP, JAMES F.: Secondary Enrichment in Ore-Deposits of Copper, *Economic Geology*, vol. i, pp. 11–25 (1906).

LINCOLN, F. C.: Magmatic Emanations, *Economic Geology*, vol. ii, pp. 258–274 (1907).

POSEPNY, FRANZ: *The Genesis of Ore Deposits*, 2d ed. (New York, 1902).

READ, T. T.: The Secondary Enrichment of Copper-Iron Sulphides, *Transactions of the American Institute of Mining Engineers*, vol. xxxvii, pp. 297, 895 (1906).

RICKARD, T. A.: Ore Deposits—A Discussion. (New York, 1905).

SULLIVAN, EUGENE C.: The Chemistry of Ore-Deposition—Precipitation of Copper by Natural Silicates, *Economic Geology*, vol. i, pp. 67–73 (1906).

WEED, W. H.: *The Copper Mines of the World*, pp. 297–302 (New York, 1907).

WINCHELL, A. N.: The Oxidation of Pyrite, *Economic Geology*, vol. ii, pp. 290–294 (1907).

DISCUSSION

E. GYBBON SPILSBURY, New York, N. Y.—There is one point in Mr. Boyle's paper on the Bully Hill Mining District which is very interesting to me as I happen to have seen the occurrence myself, and was the first to call attention to its probable significance there; I refer to the rapid development in the lower levels of the mine of the anhydrite and gypsum deposits, which have been increasing gradually from the 700-ft. level down to the present bottom, where the deposit has obtained great magnitude. The purity of the deposit is remarkable, and it occurs in the same crushed zone as the pyrite and pyritic lenses, and seems to have a good deal of influence on the continuance of the ore below the level where it first occurred.

Professor Winchell in his examination appeared to think that this occurrence marks the bottom of the mineralization, but Mr. Boyle does not agree with this conclusion. I think probably he is right, because while there is no sign of mineralization in the anhydrite and gypsum beds themselves, still there is a persistent continuance of small seams along the contact of the gypsum with the andesite of the country rock, and it is quite probable, therefore, that the gypsum will be found to be only a local intrusion of limited depth, and that the mineralization along the contact will be found below that point. I would like to ask whether anybody else knows of any of these copper deposits which have bottomed on gypsum or anhydrite? It is the only occurrence of the kind that I have ever observed.

G. A. Packard, Boston, Mass.—The deposit of the Ludwig mine of the Nevada Douglas Co. in the Yerington mining district is somewhat similar, as I remember it. It has been described by Mr. Ransome,[24] and since then by A. F. Rogers.[25] There is a difference of opinion between these two men as to the method of formation of this gypsum, whether or not it is the result of the action on the limestone of sulphuric acid from the oxidation of the sulphide ores. The deposit is partly gypsum and partly anhydrite, and there is also a question as to which mineral is the original form and which the result of alteration.

L. C. Graton, Cambridge, Mass.—A few years ago, I spent some time in the Shasta county copper region and found the occurrence of masses of gypsum in the Bully Hill and Rising Star mines of particular interest, because so unusual. In the body of some of these larger fine-grained gypsum masses there appeared some more coarsely crystalline material, which, when examined in microscopic sections, proved to be anhydrite.

As yet, I have not had opportunity to read Mr. Boyle's paper carefully. It appears, however, that he is not satisfied as to whether the gypsum was derived from the anhydrite or the anhydrite from the gypsum. Numerous occurrences have of course been described in which gypsum has been converted into anhydrite by dehydration. The structural relations of the material that I collected, however, seemed to leave no doubt that anhydrite is the original mineral and that the gypsum is altering from it.[26]

This conclusion gathers strength from the fact that at the Cactus mine, at Frisco, Utah,[27] that rather unusual type of ore contains veinlets and masses of gypsum in it, and in the deeper levels the gypsum gives way to anhydrite, from which the gypsum is being derived. Large masses of pinkish anhydrite are to be found associated with plentiful

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[24] *Bulletin No.* 380, *U. S. Geological Survey,* p. 113 (1909).

[25] *Economic Geology*, vol. vii, No. 2, p. 185 (Mar., 1912).

[26] *Bulletin No.* 430, *U. S. Geological Survey,* p. 100 (1910).

[27] Lindgren, W.: *Economic Geology,* vol. v, No. 6, p. 522 (Sept., 1910).

barite, a mineral that is also present in the Shasta county occurrence. Since seeing these two occurrences, I am inclined to believe that the gypsum associated with gold in the White Oaks district,[28] New Mexico, may likewise have been derived from original anhydrite gangue stuff. Professor Lindgren has told me that on a recent trip to Cuba he found at El Cobre mines anhydrite intergrown with sulphides, and altering to gypsum. I understand, also, that Professor Palache has found anhydrite intergrown with prehnite and datolite in the traps of Meriden, Conn., an association that points to an origin connected with vulcanism, if not with ore deposition.

The situation at the Ludwig mine, Yerington, Nev., seems to be less clear. The occurrence of gypsum in association with limestone on the foot-wall side of a thick bed of deeply oxidized sulphides suggested[29] that the sulphate of lime might have been produced, as in small amounts in other regions, by reaction of sulphuric acid waters from the ore body upon the limestone. Professor Rogers,[30] however, who later examined the mine, found that at depth the gypsum gave way to anhydrite, but he concludes that the association of the ore and the lime sulphates is wholly accidental. In any event, it is interesting to note that he finds anhydrite to be the original mineral and that gypsum is being derived from it.

With regard to the significance of gypsum and anhydrite in the Bully Hill district, I have understood that the large masses of these minerals encountered in the deeper levels have been regarded by several geologists as unfavorable occurrences, indicating the likelihood that ore of commercial grade will not be found in quantity at depths below them. One may be perhaps a little suspicious of these minerals comparatively unusual in ore occurrences. But if one grants that anhydrite is here the primary mineral, remembers that this calcium sulphate and the barium sulphate, barite, are mineralogic twins, so to speak, and recalls that not only is barite common in many ore deposits, whether rich or poor, but occurs in intimate association with much of the best ore of the Bully Hill mine, then it is difficult to find reason why the mere occurrence of calcium sulphate in this district should be regarded as either particularly favorable or particularly unfavorable for the persistence of ore.

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[28] *Professional Paper No. 68, U. S. Geological Survey*, p. 181 (1910).

[29] Ransome, F. L.: *Bulletin No. 380, U. S. Geological Survey* (1909).

[30] *Economic Geology*, vol. vii, No. 2, pp. 185 to 189 (Mar., 1912).

Nickel Deposits in the Urals

BY H. W. TURNER, SAN FRANCISCO, CAL.

(New York Meeting, February, 1914)

THE axis of the middle portion of the Ural mountains is made up chiefly of highly compressed igneous and sedimentary schists, considered of Devonian age by the Russian geologists, with large areas of serpentine (peridotite originally) gabbro, etc., intrusive in the schist series. In addition there are large areas of probably older granitic and gneissic rocks. The nickel deposits referred to in this paper are found in the Devonian schists and their associated igneous rocks. The gabbro-peridotite intrusions probably took place in late Devonian or early Permian time, inasmuch as the Permian and Carboniferous beds lie at gentle angles on the Devonian series on the west slope of the Urals.

Perhaps the first attempt to work a nickel deposit in the Urals was made about 1866 in the Revdinsk district, which is situated southwest of Ekaterinburg. I was informed by a Russian that a wet method of extracting the nickel was tried but was not a commercial success. This deposit has been described by Müller,[1] Foullon,[2] and Karpinski.[3] Beck[4] gives an abstract of these papers.

Lying to the southeast of the Revdinsk district, the Sissert estate intervening, is the Verkhne-Ufalei district, which is traversed by the railroad from Ekaterinburg to Cheliabinsk, as shown on the map, Fig. 1, there being a station on this railroad at the iron-smelting town of Verkhne-Ufalei. About 7 versts (4.6 miles) north of this town is the Nijni-Karkadinsk iron mine, which is a limonite deposit. In one of the shafts in this mine a serpentine rock showing a green mineral was encountered. A sample of this mineral collected in 1910 was tested by Mr. Wyatt, chief chemist of the Karabash laboratory of the Kyshtim Mining Works, and determined as nickel ore. A thin section of one piece of the serpen-

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[1] H. Müller: Über die Nickelerzlagerstätten von Rewdinsk, *Berg- und Hüttenmännische Zeitung*, vol. xxv, No. 8, p. 65 (Feb. 19, 1866).

[2] H. B. von Foullon: *Jahrbuch der kaiserlich-königliche geologische Reichsanstalt*, vol. xliii, pt. 2, p. 234 (1892).

[3] A. Karpinski: Über die Lagerstätten der Nickelerze im Ural, *Gorni Journal* (Russian), St. Petersburg, 1891, No. 10.

[4] *Lehre von den Erzlagerstätten*, 3d ed., vol. i, p. 518 (1909).

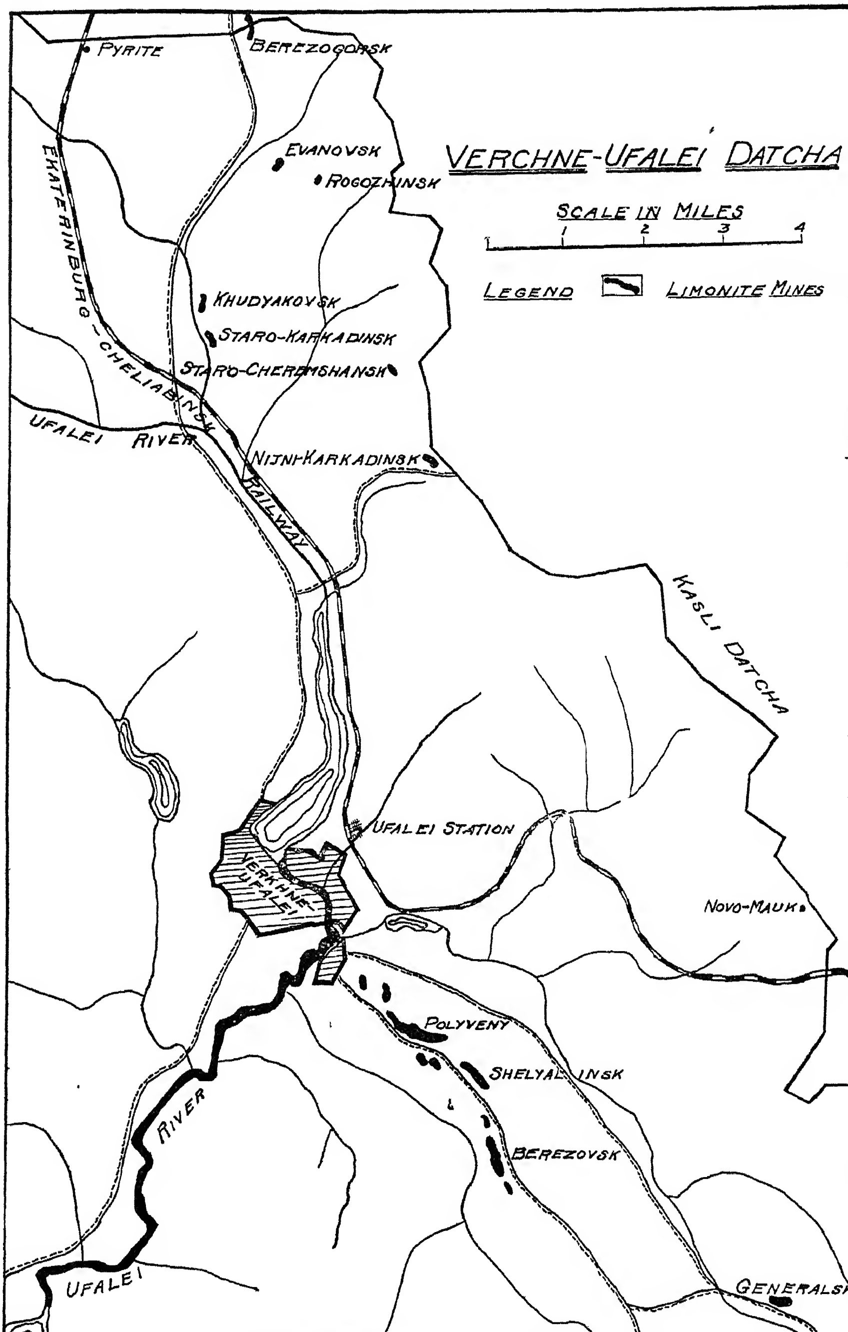

FIG. 1.—MAP OF THE VERKHNE-UFALEI MINING DISTRICT.

tine rock showed under the microscope serpentine apparently derived from olivine and the remains of orthorhombic pyroxene.

The occurrences are apparently similar in a general way to the New Caledonia deposits and those of small economic importance at Riddles, Ore., the silicate of nickel being secondary and the original nickel sulphide(?) being probably an original constituent of the peridotite from which the serpentine was derived.

In 1906–07 some prospecting for nickel was done at the Nijni-Karkadinsk mine by the foreign geologist Gannenbein, and continued in 1908 by the Russian geologist, Professor Krotoff. Some bore holes put down penetrated clay beds containing green nickel ore. The average

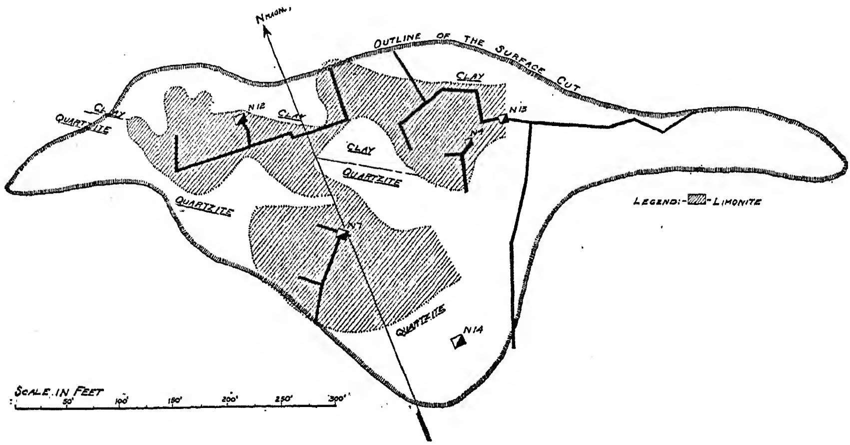

FIG. 2.—PLAN OF THE NIJNI-KARKADINSK MINE ON APPROXIMATELY THE 90-FT. LEVEL

content of nickel in the samples from four bore holes was from 0.72 per cent. in bore No. 1 to 3.24 per cent. in bore No. 4.

What is probably a continuation of the Nijni-Karkadinsk nickel silicate deposit was found about 1,300 ft. to the northwest. Here Professor Krotoff sunk about 100 pits and uncovered a considerable quantity of clay containing the green nickel ore. The horizontal extent of these workings was an area about 250 ft. long in a northwest-southeast direction and 70 ft. wide. The general average of 35 samples, as determined by the chemist of the Ufalei Iron Works, was 2.82 per cent. Ni. A sample of nearly pure ore gave the following results: Ignition, 8.40; SiO_2, 38.95; Al_2O_3, 3.45; FeO, 1.56; CaO, 0.10; MgO, 1.00; NiO, 47.00 (=37% Ni); total, 100.46 per cent.

The mineral is thus a silicate of nickel. All of this nickel silicate ore is presumably derived from the weathering of the adjoining serpentine, the nickel undergoing concentration.

In the Khudyakovsk iron mine, on the Ufalei estate, there is also nickel in the ore, assays by Johnson & Sons, of London, showing a con-

tent of from 0.08 to 0.11 per cent. of Ni in four samples and of from 0.02 to 0.04 of Cu. Here again there is a large serpentine area immediately adjoining the deposit on the east.

The Staro-Cheremshansk limonite mine, lying northwest of the Nijni-Karkadinsk, is very similar to the latter mine, the same granular quartz rock described later being present. This limonite ore also contains, in the sample assayed by Johnson & Sons, 0.95 per cent. Ni. There is serpentine to the west of the deposit, but the inclosing rocks so far as seen are the quartzite and talc-schists.

Another similar occurrence, but probably of no economic value, is at the Agardyash iron mine, on the Kyshtim estate. There is some serpentine along this deposit and green nickel ore was found carrying up to 5 per cent. Ni, according to the records of the Kyshtim laboratory.

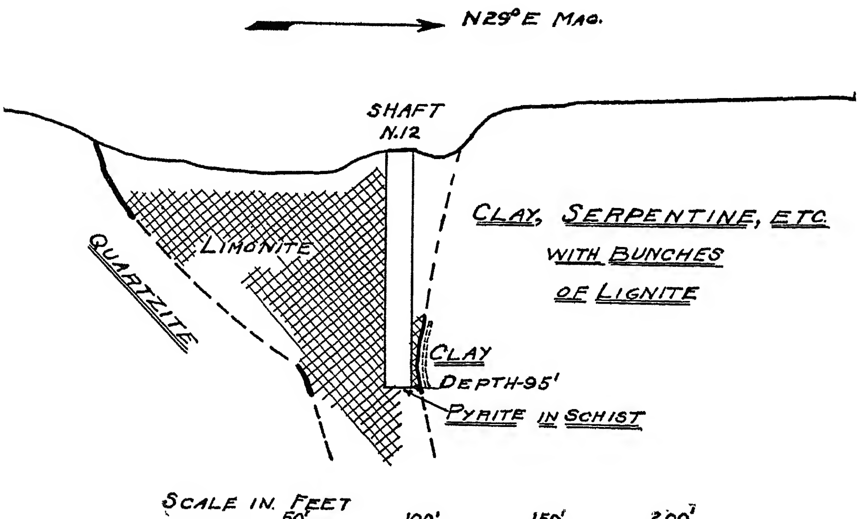

Fig. 3.—Vertical Section of the Nijni-Karkadinsk Mine.

Going further afield, the Moa Bay limonite deposits[5] of Cuba are in serpentine, the ore being a surface concentration from the decomposition of that rock. An analysis of the Moa Bay iron ore shows a content of nickel of 0.60 per cent. and of chromic oxide of 2.65 per cent. Nickel is also present in the limonite ores of Virginia where basic intrusives are absent. Thus the Oriskany (Devonian) ores contain from 0.05 to 0.1 per cent. NiO+CoO, and Potsdam (Upper Cambrian) limonite from the Blue ridge was found to contain 0.5 per cent. NiO+CoO.[6]

When prospecting for copper on the Ufalei estate in the fall of 1910,

[5] C. M. Weld: *Trans.*, xl, 299 to 312 (1909).

[6] *Trans.*, xxxix, 547 and 921 (1908).

I found at the bottom of shaft No. 12 in the Nijni-Karkadinsk mine some blue dirt containing a sulphide, apparently pyrite. The same mineral crystallized in cubical form was also found in some black dirt from another shaft. At the time this pyritic mineral was tested for copper, of which it contains traces, but it was not determined until some time afterward that it contained nickel. Later investigations showed that the pyrite was sprinkled through some of the iron ore in the bottom workings and in drill holes put down from these workings, and that carbonate of iron, or siderite, was present, and that the limonite was formed from the oxidation of the siderite.

The Tunkinsk iron mine, in the Serguinsk district, farther to the northwest, is of this nature, the bottom of workings at a depth of 150 ft. from the surface being carbonate of iron, while above that level nearly all the ore is oxidized into limonite. Here also the siderite contains a little iron sulphide showing on careful tests traces of copper. The Tunkinsk siderite ore bed is probably of sedimentary origin, and this is probably true of many of the iron mines in the extreme western part of the Kyshtim estate and of the Serguinsk district, and very likely is true of the ore bed of the Nijni-Karkadinsk iron mine.

The black dirt containing pyrite was found to be largely carbon, and this doubtless represents a bed of coal or lignite much broken up by later serpentine intrusions. A sample of the black carbonaceous material was analyzed by Johnson & Sons, of London, with the following result, the sample not being dried: Moisture, etc., 100° C., 35.65; volatile, 26.55; fixed carbon, 14.85; Ni and Co, 1.69 per cent.

Another portion of the same sample was burned, the ash and mineral matter forming 22.9 per cent. of the sample. The ash contained: Ni, 7.20; Co, 0.21 per cent.; fine gold, 0.01 oz.; fine silver, 0.50 oz. per ton of 2,240 lb.

It is thus evident that this carbonaceous ore can be concentrated by simple ignition into a commercial product, the question being largely one of quantity, which has not yet been determined.

To test the limonite-siderite deposit for nickel, 20 vertical bores were put down. The average of all the samples representing about 40,000 tons of iron ore is reported by Mr. Kerzin, the Russian geologist of the estate, to be 0.75 per cent. Ni. It is obvious that the nickel-bearing pyrite must be concentrated from the limonite-siderite gangue to be of commercial value; otherwise the only use of the nickel would be to improve the quality of the iron smelted.

The ore was subjected to an ordinary laboratory water-concentration test by Johnson & Sons, with negative results, as would be expected. A test was also made by T. J. Hoover by oil flotation, with negative results, due no doubt to the limonite present. However, as in depth the gangue may be entirely siderite, the oil-flotation method may still suc-

ceed, or some other method of concentration may be successful. Mr. Hoevelaken and colleagues in charge of the estate intended to have other tests made, but I have not been informed of the results.

A sample of the pyrite concentrated by hand panning—although not pure—contained, as reported by Johnson & Sons, 6.28 per cent. Ni. A sample of the same concentrate was examined by Prof. A. F. Rogers, of Stanford University, who reported that the "nickel-bearing sulphide has the crystal form of pyrite and lacks the octahedral cleavage of pentlandite." He also determined that siderite was present as an impurity in the concentrate. Dr. W. F. Hillebrand, who made a provisional examination of the concentrate, considers it nickeliferous pyrite.

Origin of the Nickel-Pyrite Ore

The rocks of the Nijni-Karkadinsk mine comprise talcose schists in subordinate amount, but chiefly the rock called quartzite and serpentine. The so-called quartzite may in reality represent an original sandstone much changed by the addition of secondary silica. Some of it is porous, containing many little well-formed quartz crystals and sometimes pyrite, and looks not unlike the quartz of some granular quartz veins. Whether of sedimentary or vein origin, there is no question as to the deposition of much secondary silica, presumably from deep mineral-bearing waters. The carbonaceous material (lignite?) that occurs in irregular bunches along the east side of the mine may easily have been at one time a definite layer interbedded in the original sediments and broken up into patches by the peridotite (serpentine) intrusions. It seems very possible, therefore, that the serpentine is the mother rock of the nickel-pyrite, which was brought from the serpentine in magmatic or other solutions which soaked into the adjoining siderite deposit and into the lignite bed and deposited there their mineral contents. The same solutions very likely account for the quartzite as we now see it.

A plan, Fig. 2, and a vertical section, Fig. 3, of the Nijni-Karkadinsk mine are given herewith. While the rock immediately west of the limonite deposit is quartzite, a little farther west is a large serpentine area which extends for miles north and south. There is thus serpentine both east and west of the mine.

Kemp[7] states that the ores of Mine La Motte and Bonne Terre, in Missouri, are nickeliferous pyrite and (at the former in a subordinate way) siegenite, a sulphide of nickel and cobalt with a little iron. The pyrite is disseminated with galena in Cambrian limestone, while the siegenite is in an underlying sandstone. Small amounts of copper also appear in the mattes.

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[7] *Trans.*, xxiv, 620 (1894).

Dana states that nickeliferous pyrite has been observed at Sudbury, Canada.

Hillebrand[8] has described a nickeliferous pyrite from an asphaltite-vanadium deposit at Minasragra, Peru, having a composition as follows: Sulphur, 45.06; iron, 25.38; nickel, 15.70; cobalt, trace; vanadium, 4.31; molybdenum, 0.09; carbon, 0.47; water (H_2O), 1.38 (partly from H of carbonaceous matter); titanic acid (TiO_2), 0.93; silica (SiO_2), 1.93; alumina (Al_2O_3), with a little P_2O_5, 2.45 per cent.

Hillebrand remarks: "If the vanadium is disregarded, the iron-nickel sulphide has the formula $(FeNi)S_2$, with iron to nickel as 1.70 to 1, or nearly 5 to 3. A pyrite with such a high proportion of nickel is unknown. But a single one of the analyses quoted in Hintze's Handbook of Mineralogy shows anywhere near 6 per cent. nickel; this one, however, showing also about 3 per cent. of cobalt. The nearest approach to the present case is seen in the mineral gunnarite, $3FeS_2$, $2NiS$, incompletely described by Lanstrom with density 4.3 and a tin-white color with a tinge of yellow, tarnishing yellowish-brown. The present mineral would seem to be quite distinct from gunnarite, and for the present is to be regarded as a highly nickeliferous pyrite. Should it seem proper to give it a specific name later, *bravoite* is suggested, after Señor José J. Bravo, the Peruvian writer on the vanadium occurrence at Minasragra."

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[8] Hillebrand, W. F.: The Vanadium Sulphide, Patronite, and Its Mineral Associates from Minasragra, Peru, *Journal of the American Chemical Society*, vol. xxix, No. 7, p. 1019 (July, 1907).

Cyanidation of Silver Sulphide at Ocampo, Mexico

BY ROBERT LINTON, LOS ANGELES, CAL.

(New York Meeting, February, 1914)

THE Sierra Consolidated Mines Co., organized in 1909, owns, together with other holdings, practically all of the productive mineral area in the Ocampo district. Lying within this area are 15 mines, large and small, that had previously been worked and appear to have yielded, since the discovery of the camp, about 100 years ago, bullion of a total value of over $50,000,000. The deepest mine, the Santa Juliana, had been worked to 1,100 ft. below the outcrop. The reopening of the mines involved, first, extensive and thorough development to open up the known ore shoots at greater depth and explore the ledges for additional shoots, and, second, a revision of existing equipment and methods, so as to increase output and reduce cost of production. This paper will give some account of the metallurgical treatment and a description of the new mill to be built at El Salto.

The Ore

The ore is practically all argentite, Ag_2S, with some associated gold, and carried in a siliceous gangue. The typical ledge matter is an andesitic breccia cemented with quartz, or quartz stockwork in andesite.[1] The proportion by weight of silver to gold averages about 60 to 1. The silver sulphides occur ordinarily in rather fine dissemination, sometimes not being easily discernible with the naked eye, even in ores of very good grade. The ledges also contain considerable pyrites, which as a rule is barren. "Bronce" is the local term applied to such barren pyrites, and "Pasta" to such as carries values.

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[1] The geology of the Ocampo district is described in the *Engineering and Mining Journal*, vol. xciv, No. 14, p. 653 (Oct. 5, 1912).

Analyses of ores from three of the principal mines are as follows:

	Per cent.	Per cent.	Per cent.
Insoluble	82 50	82.15	83.80
Fe	3.70	5.05	2.47
CaO	4.75	3.55	4.50
MgO	3.27	3.75	1.42
S	0.22	0.50	0.20
Al_2O_3	1.61	2.34	2.13
MnO_2	0.55	0.28	0.31
Cu	0.01	Nil	Nil
As	Nil	Trace	Nil
Sb	Trace	Nil	Nil
Loss in ignition	2.41	2.00	4.20
	99.02	99.62	99.03
Ounces Ag	16 55	88.30	11.10
Ounces Au	0.25	1.08	0.36
Acidity of ore (terms NaOH)	0.20	0.39	0.25

The proportions of the metallic constituents of the ore are better shown by the analyses of concentrates and concentration tailings, as follows:

	Concentrates Per cent.	Tailings Per cent.
Insoluble	31.40	86.30
Fe	32.00	2.80
CaO	2.40	3.40
MgO	0.60	0.80
S	17.90	0.36
Al_2O_3	0.70	1.78
MnO_2	0.47	0.57
Cu	1.10	Nil
As	0.28	Trace
Sb	Trace	Nil
Ounces Ag	1,376.00	11.20
Ounces Au	23.40	0.15

Recasting the analysis of the concentrates, the mineralogical composition would be about as follows:

	Per cent.
Iron pyrites	30.2
Chalcopyrite	3.0
Arsenopyrite	0.7
Argentite	5.4
Total sulphides	39.8
Oxides and silicates	49.0
Carbonates	5.4
Metallics	5.8
	100.0

Previous Milling Practice

Six mills had been operated in connection with the mines now owned by the company—the Guadalupe, Santa Juliana, Belen, San Ramon, Rosario, and El Salto. The San Ramon used Bryan mills for crushing, all of the others light stamps, the total capacity aggregating 90 stamps. All of these mills but the one at El Salto had been out of operation for some time, and had been dismantled.

Until about seven years ago, the treatment followed was plate-amalgamation, or more frequently pan-amalgamation, followed by concentration on Wilfley tables and vanners, with pan-amalgamation of the concentrates. Records of these milling operations are very incomplete, and probably not very reliable as regards the extraction obtained. A general idea of the results may be gained from the following extracts from these records:

Mill	Extraction Au Per cent.	Extraction Ag Per cent.	Bullion Fineness	Milling Costs Per Ton
Santa Juliana	62	55	946	$4.09
San Ramon	79	64	981	....
Belen	64	46	991	5 01
Rosario	73	51	971	3 25

The above extraction figures are based on the assays of heads and tailings. The actual recovery made in these old pan-amalgamation mills probably did not average over 60 per cent. of the gold and 50 per cent. of the silver in the ore.

The first cyanide plant in Ocampo was installed in 1906 at the pan-amalgamation mill at El Salto. The equipment consisted of one Farrel and one Sturtevant rock breaker; twenty 850-lb. stamps with Challenge feeders; three Wilfley tables; two sands-collecting tanks 15 ft. in diameter by 6 ft. deep, provided with Butters and Meins distributor; eight leaching tanks 15 ft. in diameter by 6 ft. deep; two slimes-collecting tanks 15 ft. in diameter by 6 ft. deep with cone bottoms; five Pachuca agitating tanks 12 ft. in diameter by 20 ft. deep; clarifying filter press; solution storage tanks and sumps; zinc-boxes, drier and melting furnace; small air compressor for agitating the Pachuca tanks; steam pumps for circulating water and solutions; grinding pan and settler for treatment of concentrates.

In this mill the battery pulp was run over Wilfley tables and the coarse sulphides were concentrated out, to be then treated by grinding in strong cyanide solution in one of the old amalgamating pans. The sands were drained as dry as possible in the collecting tanks and transferred to the leaching tanks in a small car; the thickened slimes (about 2.5:1) flowed directly to the Pachucas. The sands treatment appears to have

required about 20 to 25 days and the slimes treatment 8 to 10 days, of which about 30 to 35 hr. was actual agitation in strong solution, the remainder being taken up with decantation and washing According to such records as are available the average recovery at this mill was about 70 per cent. for both gold and silver, and the cyanide consumption per ton of ore more than 5 lb., a considerable portion of which was lost in waste solutions. Milling costs averaged about $5 per ton.

Recent Operation

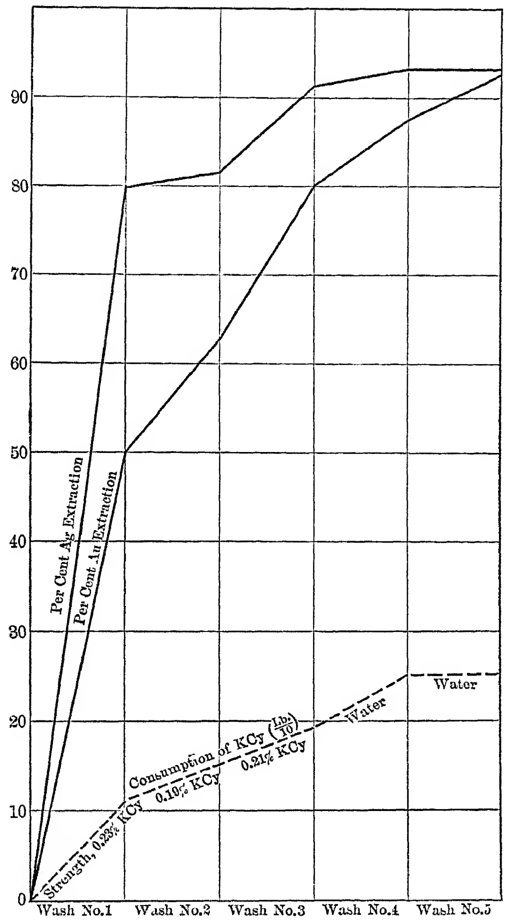
On account of the worn-out condition and inefficient arrangement and equipment of this cyanide mill, no attempt was made by the new company to operate it regularly; but it was utilized with advantage in test runs to determine the details of treatment that would yield the best commercial returns, considering extraction, cost, and time required. The ore milled, being only what was produced in the course of development work, amounted to 4,700 tons, from which bullion worth $45,273.86, U. S. currency, was produced.

As the Pachuca tanks operated in parallel, it was easy to vary the treatment on individual charges of slimes, as well as sands, and in this way improved results were soon obtained. The time of treatment of the sands was reduced to 18 days, concentration was eliminated, a *spitzlütte* was placed ahead of the Butters distributor, the proper strength of solution was determined and the percentage of extraction was materially raised. Careful records were kept of the individual charges under special treatment and the results were plotted graphically. One of these curves is shown in Fig. 1, which shows the extraction of gold and silver and the consumption of cyanide and lime in connection with a charge of 20 tons of slimes. The results shown by the curves are metallurgical and do not take into account the additional losses, both of values and materials, that occur mechanically.

The operation of the mill showed conclusively that leaching should be eliminated. Where the treatment of the individual slimes charge was considered separately, and compared with the sands charge under treatment for the same length of time, the latter would contain at least three times as much gold and four times as much silver as the slimes residues. In the slimes charge shown in Fig. 1, 80 per cent. of the silver was dissolved in the first agitation with strong solution, lasting 20 hr., while the total extraction of silver in the sands rarely reached 75 per cent. at the end of 18 days.

Special Investigations

A large number of laboratory tests were carried on at the same time, concerning questions of sizing, chemical conditions influencing treatment, and tests on slimes charges of from 25 to 50 lb.



Total time agitated, 35 hr.
Total time settling, 144 hr.
Heads assay: Au, 0.08 oz.; Ag, 11.62 oz.
Au extraction, 92.5 per cent.
Ag extraction, 93.3 per cent.
Total KCy consumption, 2.5 lb. per ton slime.

FIG. 1.—CURVE SHOWING RESULTS ON A CHARGE OF 20 TONS OF DRY SLIME.

Sizing

A number of sizing tests were made and the various products assayed. The screen assay of a characteristic sample of battery pulp, crushed to pass a 26-mesh screen, was as follows:

	Proportion of Total Weight	Assay per Ton		Contents	
		Au	Ag	Au	Ag
	Per cent.	Oz.	Oz.	Oz.	Oz.
On 40 mesh	4.0	0.16	7.8	0.006	0.31
Through 40 on 50	10.0	0.12	7.9	0.012	0.79
Through 50 on 60	4.3	0.12	8 9	0.005	0.38
Through 60 on 70	12.5	0.12	9.7	0.015	1.21
Through 70 on 90	9.0	0.12	9.9	0.010	0.89
Through 90 on 100	12.0	0.12	12.1	0.014	1.45
Through 100 on 120	4.7	0.12	4.11	0.005	0.66
Through 120 on 150	5.0	0.16	14.8	0.008	0.74
Through 150 on 200	19.5	0.16	17.5	0.031	3.41
Through 200 mesh	19.0	0.16	18.8	0.030	3.57
Combined sample	100.0	0.15	13.2	0.136	13.41

It will be noted that the gold is rather evenly distributed throughout all the sizes, but that there is a gradual increase in silver values in passing from the coarse to the fine sizes. Fine grinding is therefore necessary to expose the silver sufficiently to the dissolving action of the cyanide solution. The sizing tests indicate that the more nearly the ore is ground to pass 200-mesh, the better will be the extraction obtained.

Chemical Conditions Influencing Treatment

The elements unfavorable to cyanide treatment, such as copper, arsenic, antimony, and sulphur, if present at all in this ore, occur in such small quantities as to exert practically no influence on the treatment. As to the manganese, the silver values do not appear to be in any case combined with it to form a refractory manganiferous silver ore, such as is somewhat frequent in Mexico.[2]

The water from the Jesus Maria arroyo, on which the mill is situated, was found to contain 77 parts solids per 100,000, the constituents of the solids being as follows:

[2] Experiments on such an ore are described in a paper by the writer published in the *Journal of the Chemical, Metallurgical and Mining Society of South Africa*, vol. x, No. 3, p. 74 (Sept., 1908).

	Parts
SiO_2	10.8
Fe_2O_3 Al_2O_3	6.8
CaO	41.4
MgO	Trace
SO_3	8.0
Cl	8.0
Organic and volatile	2.0
Total	77.0

Experiments on cyanide consumption by the arroyo water showed that after six hours' contact a quantity of cyanide had been consumed equivalent to 0.44 lb. KCy per ton of water, which was reduced to 0.11 lb. KCy per ton of water when alkali was added. A branch of the main arroyo flowing into it at the mill carries pure water, which did not attack the cyanide. The tests were made when the stream was at a low stage and the water naturally carried more impurities than would be the case during the greater part of the year.

The supply of lime heretofore available is quite impure, but contains nothing prejudicial to cyaniding. The analysis of an average sample of burned lime is as follows:

	Per cent.
SiO_2	8.8
CaO	54.8
MgO	4.5
Fe_2O_3	1.9
Al_2O_3	3.2
CO_2	13.9
H_2O	12.2
Total	99.3

Of this lime, 50 lb. digested for 6 hr. with a ton of standard KCy solution showed no cyanide consumption; hence the material could be used. After considerable search, however, a better grade of lime has been found, which can be obtained at a slightly higher cost.

Recasting the analysis of an average sample of battery heads for one month, and the analysis of the lime, water, and cyanide used, we find the chemical composition of the consolidated mill charge, as given below. In this month 40 lb. of lime was used per ton of ore; the ratio of solution to ore was 6:1; the strength of solution, 0.23 per cent., 120 per cent. sodium cyanide being used. The solids in the charge per ton of ore milled would be made up approximately as follows:

	Pounds		Pounds
Insoluble	1,755.29	CN	14.63
Fe	55.00	As	0.10
Fe_2O_3, Fe_3O_4	1.00	CO_2	77.70
		S	33.60
Al_2O_3	24.87	SO_3	0.08
CaO	114.41	Cl	0.08
MgO	0.80	Au	0.025
Cu	0.20	Ag	1.44
MnO_2	10.00	Volatile, Organic	0.09
Na	12.97		

Special Tests on Small Samples

A model Pachuca tank 10 in. in diameter by 30 in. high and connected with small zinc-boxes was rigged up for experimental work. From 25- to 50-lb. samples were treated in this, and the details of treatment were worked out here and subsequently checked by agitation of 20-ton charges in the cyanide plant. The ore was ground to 120-, 150-, and 200-mesh; solutions of different strengths were used; and the various conditions influencing the treatment were thoroughly tested. Without going into the numerous details, the results may be summarized as follows:

It was not possible to obtain nearly as high extraction with pulp ground to 120- or 150-mesh as with that ground to 200-mesh—demonstrating the necessity of fine grinding.

The strength of solution most favorable for the treatment of this ore is about 0.32 per cent. KCy. Weaker solutions can be used to obtain equally high extraction if the time of treatment be increased. With this strength of solution the period of agitation necessary for extraction percentage as given below was 34 hr.

Protective alkalinity should be maintained during agitation up to 0.08.

The use of lead acetate was found to be of no benefit in connection with the treatment.

With the treatment as outlined above, the consumption of cyanide averaged about 1.4 lb. and that of lime about 12 lb. per ton of ore treated. These are the actual amounts of materials destroyed by the reactions of the process. Including mechanical losses, there would probably be in a working plant a consumption of about 2.5 lb. of 98 per cent. potassium cyanide, and 15 to 20 lb. of lime per ton of ore treated.

The extraction of silver from samples ground to 200-mesh varied from 84 to 89 per cent.; the gold extraction from 93 to 95 per cent. A recovery of 85 per cent. should be effected in operating.

Cyaniding Concentrates

A series of tests was also made on cyaniding the concentrates. The writer has already given details of these in a previous paper.[3] The results indicated that the most economical treatment was to grind the concentrates in 0.2 per cent. KCy solution, and agitate in a 0.6 KCy per cent. solution which was raised to 0.8 per cent. toward the end of the treatment, the protective alkalinity being maintained at 0.10. The use of lead acetate did not benefit the extraction; but a small amount assisted in keeping the solutions clear. In treating ore of ordinary grade, there is no benefit to be derived from concentrating. It may be of advantage in handling the rich ore from bonanza shoots such as appear to be characteristic of the ore occurrence here, having been encountered from time to time in the past. In the new mill, concentrating equipment is not provided, but the mill is so designed that this can be added when needed.

The New Mill

After the metallurgical details had been worked out a new cyanide mill was designed, which follows closely the outline of treatment derived from this preliminary work. The site selected was El Salto, where the old cyanide mill was located, since it is the most favorable as regards both the contour of the ground, and transportation of ore from the mines. The machinery for the first unit of this mill was ordered and construction work had been begun when it was decided to suspend operations until political conditions in Mexico should become more settled. The equipment for this first unit consists of the following:

One 20- by 10-in. Armour cast-steel Blake Marsden type rock breaker.

One battery of ten 1,500-lb. stamps, with open-front mortars, fluted cam shaft, Blanton cams, individual El Oro guides, Nelson suspended automatic feeders.

One Newago screen.

Two 4 by 20 tube mills, roller bearing on discharge end, trunnion bearing on feed end, connected by single reduction gear to special type I 24 General Electric high-torque motors.

One Esperanza type classifier, 20 ft. 7 in. by 4 ft. by 3 ft. 8 in. maximum depth.

One 40- by 16-ft. Dorr thickener, with tank.

One 35- by 12-ft. Dorr thickener, with tank.

Three standard 15- by 45-ft. Pachuca agitators.

One 10- by 12-ft. tank with mechanical agitator.

One Oliver continuous slime filter, 125 tons capacity per 24 hr.

One Gwynne solution multistage centrifugal volute turbine pump, capacity 250 gal. per minute against 150 ft. head.

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[3] *Journal of the Chemical, Metallurgical and Mining Society of South Africa,* vol. xiii, No. 1, p. 14 (July, 1912).

Two 4-in. Gwynne centrifugal slime pumps.
One 10- by 12-ft. slime receiving tank.
One 35- by 16-ft. main solution tank.
Two 16- by 10-ft. pregnant solution tanks with clarifying sand filters.
Two 20- by 14-ft. sump tanks.
Two double-column zinc-boxes.
One 5- by 5- by 6-ft. clean-up tank.
One S. H. Johnson precipitate press.
One tilting furnace of the Butters type, for No. 400 crucible.
One Hampton zinc lathe.

The rock breaker, stamp mill, and tube mills are manufactured by the English firm of Fraser Chalmers.

The compressor to furnish air for the Pachuca agitators, and some other minor items, will be furnished from equipment previously on hand.

Outline of Treatment

The ore from the mines is received in a small bin above the rock breaker, and crushed in the latter to 2-in. size. It is then delivered by a belt conveyor to a Newago screen above the battery ore bins which constitute the main storage. Material coarser than $\frac{3}{16}$ in. goes to the battery bins and the fines go to a separate bin at one end. The fines are delivered by a belt conveyor directly to the classifier. The oversize is crushed in the battery to 5-mesh and passes to the classifier. The classifier is set between the two tube mills and receives the tube-mill discharge as well as the battery pulp, constituting a closed circuit with constant overflow of slimes. It is estimated that the ratio of solution to ore in the tube-mill feed will be 6 to 1.

The overflowing slime is pumped to the primary thickener, where it is thickened to a 2 to 1 consistency, the overflowing solution being returned directly to the battery. The thickened pulp flows to the Pachuca agitators, which are connected in series for continuous agitation. Cyanide is dissolved in a small tank above the agitators, and added to the slime as required to maintain the solution at proper strength. At the estimated capacity of the mill the pulp would require 55 hr. to make the circuit of the tanks. The surplus agitator capacity is to provide against loss of values by a portion of the slime passing from one tank to the next before it is thoroughly agitated, and to prevent cutting down the capacity of the mill when a tank has to be put out of service temporarily, as for instance through accumulation of slime on the bottom. The arrangement is such that any tank can be thrown out of the circuit and the slime by-passed.

From the Pachucas the slime passes to the secondary thickener, where the ratio of solution to dry slime is reduced to 1.5 to 1. It then passes to

the mechanical agitator, and barren solution of the lowest grade available is added and the whole thoroughly agitated, effecting a preliminary washing and dilution. It is then filtered in the Oliver filter and the residues are washed and discharged. It is estimated that these residues will carry 30 per cent. solution, to make up for which and for evaporation will probably permit the use of a quantity of wash water equivalent to 60 to 70 per cent. of the tonnage of ore milled.

The overflowing solution from the secondary thickener and the solution from the Oliver filter flow to the clarifying sand filters, thence to the zinc-boxes and barren-solution sumps. The barren solution is pumped to the mill-solution tank above the battery.

The designing of the mill and selection of equipment has kept in view the larger capacity that will probably be required ultimately. Units of the same capacity as this first one can be added as rapidly as needed without any interruption in operating at the existing capacity.

The Injection of Cement Grout into Water-Bearing Fissures

BY FRANCIS DONALDSON,* NEW YORK, N. Y.

(New York Meeting, February, 1914)

THE direct injection of cement grout into water-bearing fissures as a means of checking or stopping the flow of water into shafts and tunnels has been experimented with for a decade or longer and seems to have been first attempted in Europe. The earliest application of which the writer has found a record was at a shaft sunk by the Mining Society of Lens; this is described by C. Dinoire in the *Transactions of the Institution of Mining Engineers*.[1]

It is only lately, however, that the process has been entirely successful. This success has been accomplished on the Catskill Aqueduct, now under construction by the city of New York. This aqueduct includes a number of deep pressure tunnels, reached by shafts for both waterway and construction purposes. In portions of these shafts and tunnels considerable underground water was met. The contract for the first of these deep pressure tunnels was let to the T. A. Gillespie Co.; this section is known as the Rondout Siphon. It leads under the Rondout valley at a depth of from 400 to 800 ft. and is about 5 miles long. The engineers expected that considerable water would be encountered, but fortunately this was not the case except at one shaft, known as No. 4, which penetrated the rock at a junction between limestone and conglomerate. Water-bearing fissures were encountered almost immediately. At a depth of about 200 ft. a flow of 1,500 gal. per minute was struck. The shaft then contained as many pumps as could be used, and it seemed impossible to sink it further. After vain efforts had been made to proceed, John P. Hogan, a division engineer of the Board of Water Supply, suggested that cementation of the fissures be tried. The process was attempted for the first time in this country. Since the shaft was partly full of water it was necessary to drill grout holes with a diamond drill. Platforms were placed on the timbers at the water level, the diamond drill was installed and six 90-ft. holes were drilled in the bottom of the shaft. Several car loads of cement were pumped through these holes into the fissures, the drill casings being used for grout pipes. This largely cut off the flow of water from the bottom and sinking could then

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* Non-member.

[1] Vol. xxxi, pp. 113 to 122 (1905–06).

proceed. After that, water-bearing seams were grouted as soon as encountered, and the contractor was able to finish the shafts and tunnel within the contract time. Shaft No. 4 was a rectangular, timbered construction shaft with no concrete lining; consequently it was impossible to cut off any of the water coming in from above the point where grouting was first attempted. On this account large volumes of water had to be pumped until the tunnel was finally sealed.

At the next wet shaft the writer had to do with, advantage was taken of the experience gained at shaft No. 4. At this second shaft, No. 4 of the New York City Siphon, good progress was made until a depth of about 100 ft. was reached. The first hole drilled in the bottom below this depth struck a stream of water; the flow amounted to about 150 gal. per minute. This was plugged. It was found that each of the 12 holes in the sump cut encountered the same stream of water.

As soon as each hole cut the water-bearing seam it was plugged with a tapered wooden plug. After all the holes in the sump had been drilled and plugged in this way, the grout connections were made one at a time, so as to restrict the flow of water into the shaft. Each connection was made with a piece of 2- or 2.5-in. iron pipe about 3 ft. long, threaded at one end and given a long taper at the other. The tapered portion was made rough on the outside by nicking it with a chisel. A heavy iron stopcock was screwed to the pipe, the tapered end wrapped in several thicknesses of burlap, the wooden plug removed from the drill hole and the tapered pipe driven in, the stopcock being left open. This was the most exciting and the wettest part of the job. After the pipe had been driven in hard the stopcock was closed.

In this case connections were placed in all the wet holes before grouting. The grouting machine or tank used on the aqueduct was the Caniff machine, in which the grout is mixed by air. It is built like an air lock with a door on the top through which cement, sand, and water are introduced, and has a 2-in. discharge opening in the bottom and air connections top and bottom. The discharge opening is connected to the grout hole by a heavy rubber hose. Another 2-in. stopcock is placed at the outlet of the tank and a 2- by 1-in. tee is placed between the hose and the cock attached to the pipe in the drill hole. Into the side opening of this tee a 1-in. stopcock is screwed.

The machine is installed at the bottom of the shaft, and is connected to one of the holes and also to the high-pressure air supply. The 2-in. stopcock on the machine is closed and the other is opened. The door in the top is opened, a sack of cement, three or four buckets of water, and (if the cavity to be filled is large) a sack of fine sand are poured in, the air connection at the bottom is opened and the air allowed to bubble through and mix the grout. Then very quickly the door is closed, the lower air connection is closed, and the discharge connection and the

upper air connection are opened, and the air enters and drives the grout into the cavity. A man stationed at the 1-in. stopcock keeps opening it a crack; when air shows instead of grout he closes the 2-in. stopcock and the machine is recharged. If the cavity is open the charge is pushed in in 3 or 4 sec. By working continuously more than 1,000 batches can be placed in 24 hr.

The grouting of the fissure was successful and sinking was resumed. About 50 ft. further down another water-bearing fissure was drilled into, and this, instead of being open, was filled with sand formed by the crushing of metamorphic gneiss due to folding; this sand was carried up out of the drilled holes in large quantities by the water. Grout will not permeate sand and it was necessary to continue drilling holes and pumping in grout, increasing the pressure at the end from 100 to 400 and 500 lb. to the square inch. The sand was tamped so full of cement that when cut through it was compacted like sandstone and contained balls of grout from the size of a fist to as large as a man's head.

The most difficult grouting on the aqueduct was done on the Hudson Siphon, which is a deep siphon tunnel under the Hudson river at a depth of 1,100 ft. below tidewater. The shafts were sunk by the city forces, after which the contract for the driving and lining of the tunnel and lining the shafts was let. About 150 ft. from the foot of the east shaft the heading cut a water-bearing fissure which flowed about 300 gal. per minute. The full flow did not develop until the cut was blasted. The problem then was to grout this flow against a hydrostatic pressure of 500 lb. per square inch, with no solid rock to which to make grout-pipe connections. This problem was finally solved by the construction of a concrete bulkhead 8 ft. thick across the full section of the head. The concrete was mixed in proportions of 1:2:4 and was heavily reinforced with rails set into holes drilled laterally into the sides, roof, and floor of the tunnel. Grout pipes leading into the fissure were set through the bulkhead. After the concrete had set for a week, grout was forced into the fissure, first by the pneumatic process with a high-pressure air compressor and finally by means of a high-pressure plunger pump which forced water instead of air into the grout tank. Pressures were reached in this way up to 1,000 lb. per square inch.

In driving or sinking through rock containing a large number of seams carrying small quantities of water, it is not practicable to stop and grout each seam as described above. In this case it is advisable to increase the section of tunnel or shaft sufficiently to allow for a heavy concrete lining. Drains should be provided opposite all of the water-bearing fissures to carry off the water while the lining is being placed. After the concrete has secured sufficient strength, the drains may be grouted. By a combination of these two methods it should be possible to penetrate any firm rock, no matter how much water it contains.

Discussion

Frank Firmstone, Easton, Pa.—The European experience referred to by the speaker has been fully described in the *Bulletin de la Société de l'Industrie Minérale.*[2]

There is another very obvious application of the plan of grouting a fissure that I do not think has been made. In the limestone region around Easton there are many layers of limestone which have been shattered in the course of the flexure of the rocks, which have been filled with pieces of limestone, varying from pieces the size of your head and fist to very small stones. A seam full of loose boulder stones is something an artesian well driller does not care to encounter. It is a very obvious expedient to grout such seams shut. I do not think any one has done it.

G. S. Wright.—In 1908 I visited the Pas-de-Calais district in France and observed there the methods which were being used for cementation. At that time they had been pretty well worked out, so that one of the large companies, the largest company, had in sinking its shafts put aside its freezing-plant methods, and adopted the cementation method. The plan that they were then following, and I think are still following, is to take about 12 to 16 holes, put down bits about 15 or 20 ft. deep, and plug these up with concrete around the pipe in order to get an anchorage, then use a grout pump, drill down, and continue to pump in under high pressure. The first step may have been by gravity, but in 1908 they adopted a pressure of about 600 lb. per square foot. They recommend that in certain cases it may be as high as 1,000 lb. per square foot. The system worked out more cheaply than the cementation process. As many of you may know, the carbonates are very lean in the Pas-de-Calais district and adjoining the Beltin district, and the marls and chalks are very fragmentary, and filled with air, so that it is impossible in places to sink by any ordinary system, and this method is in vogue in those locations.

Alfred C. Lane, Tufts College, Mass.—The author of this paper, in saying that cementing fissures by grouting was first tried in this country, evidently was not aware that the process was successfully used by E. F. Bradt, of the Lake Superior Mining Institute, under very great difficulties, in putting down the first salt shaft in Michigan, at Oakwood, just outside South Detroit, in 1904.[3] There the Devonian Dundee formation which overlies the Silurian salt beds was full of crevices, regular caves, heavily charged with strong H_2S water.

[2] R. Fagniez: 4th ser., vol. ix, p. 81 (1908). J. B. Forge: 5th ser., vol. iii, p. 625 (1913).

[3] E. F. Bradt: Crevices in a Salt Shaft, *Michigan Engineer*, 1907, p. 16. *Mining World*, vol. xxx, No. 12, p. 525 (Mar. 20, 1909). *Engineering and Mining Journal*, vol. xci, No. 11, p. 565 (Mar. 18, 1911).

Mr. Bradt has a patent on the process, which is briefly: the "displacement of the water by forcing it back into the rock or ground by injecting 'neat' cement grout under pressure," No. 849043, dated Apr. 2, 1907.

E. Gybbon Spilsbury, New York, N. Y.—I think that a somewhat similar process to that described by Mr. Donaldson was used in the sinking of the Franz-Frederic shaft in Mechlenburg about the year 1901–02. After passing through the alluvials consisting of gravels, sands, and clays, the shaft, which was being sunk by the Kindt-Chaudron method, was footed in compact anhydrite at, I think, 1,100 ft. in depth. While continuing through the anhydrite with the regular cutting tools, a fissure was encountered with a considerable pressure of water, and the cutting tools were lost at this point. It required very nearly a year's hard work to break up the cutting ring and remove the particles. The shaft was 21 ft. in diameter. I understand that a shield, having a central opening, was lowered to the bottom of the shaft, and that grout, under hydraulic pressure, was then forced through the central pipe over the whole surface of the bottom of the shaft, so as to fill up the fissures and hold the water back. When this had been successfully accomplished new cutting tools were introduced and the grout in the bottom of the shaft was passed through with practically no leakage showing from the fissures.

The Equilibrium Diagram of the System Cu_2S-Ni_3S_2

BY CARLE R. HAYWARD, BOSTON, MASS.

(New York Meeting, February, 1914)

THIS work was first undertaken in the metallurgical laboratory of the Massachusetts Institute of Technology in 1907 by L. A. Dickinson, E. Phelps, and V. S. Rood, under the author's direction. They attempted to determine the diagram for the system Cu_2S–NiS, but several inexplicable results were obtained. The following year, P. H. Mayer with Mr. Dickinson carried on some experiments with nickel sulphide and found that the molten material slowly lost sulphur until it reached a composition corresponding to the compound Ni_3S_2, established by Bornemann.[1] At this point the composition remained stable. The freezing points of the mixtures gradually fell off with the loss of sulphur.

Since the above facts seemed to explain the erratic results obtained in the first experiments, Mr. Mayer with F. Jaeger attempted in 1910 to establish a correct equilibrium diagram for the Cu_2S–Ni_3S_2 series. They prepared pure Cu_2S and Ni_3S_2 and determined the cooling curves for various mixtures. The fusions were made in a platinum resistance furnace and the temperatures were measured with a platinum-iridium thermocouple connected with a Sullivan galvanometer. The curve was established for mixtures containing more than 40 per cent. Cu_2S, but they were unable to determine certainly the direction of the curve beyond that point.

Nothing further was attempted with this series until the present year, when the work was carried to a successful conclusion with the assistance of A. Butts, Jr., and E. H. Weil. The results of this work are given in the following pages.

Preparation of Cu_2S.—A piece of cathode copper from the Buffalo plant of the Calumet & Hecla Co. was cut into shavings by a shaper and converted into sulphide by heating in boiling sulphur. A porcelain casserole was used for the purpose, the heat being furnished by a Bunsen burner. It was found that after boiling in the sulphur for an hour the copper shavings were completely converted into sulphide. The liquid sulphur was then poured off, leaving the solid sulphide in the casserole in

[1] *Metallurgie,* vol. v, No. 1, p. 13 (Jan. 8, 1908).

the form of a porous mass, each particle of which retained in general the shape of the copper shaving from which it was formed.

When cold, the sulphide was removed from the casserole, broken into small pieces, mixed with 15 per cent. of its weight of flowers of sulphur and melted in a graphite crucible under a cover of charcoal. The sulphide was kept in a molten condition for 5 hr. and then allowed to cool in the crucible.

The analysis of the material thus obtained was: Cu, 79.18; S, 20.24;

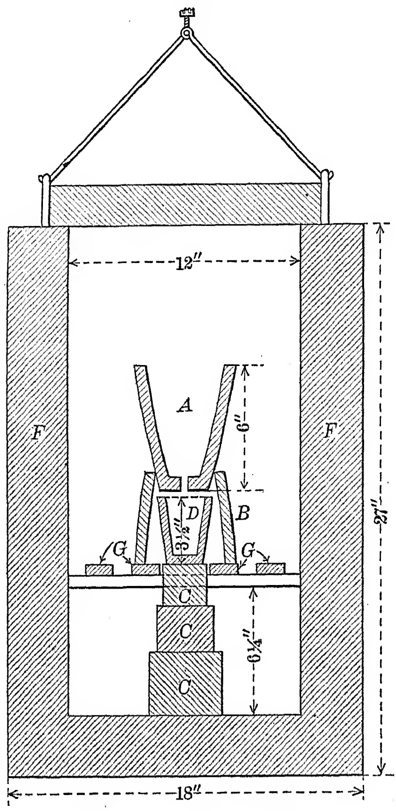

Fig. 1.—Pot Furnace.

Fe, 0.43; insoluble, 0.24; total, 100.09 per cent. The composition, calculated from the above analysis, was as follows: Cu_2S, 99.13; FeS, 0.68; SiO_2, 0.24; total, 100.05 per cent.

Preparation of Ni_3S_2.—The Ni_3S_2 was prepared from sulphur and electrolytic nickel. The latter was furnished by the International Nickel Co., and the analysis as given by them was: Ni, 98.90; Co, 0.9; Fe, 0.14; Cu, 0.02; total 99.96. Since the behavior of Co is very similar to that of Ni, there will be little error if the small amount present is included with the Ni.

The apparatus used for preparing the sulphide is shown in Fig. 1. *F* represents the walls of one of the laboratory pot-furnaces with grate bars *G*. A size K Battersea crucible was cut off about 2 in. from the bottom and placed as shown at *B*. A second crucible of the same size, with

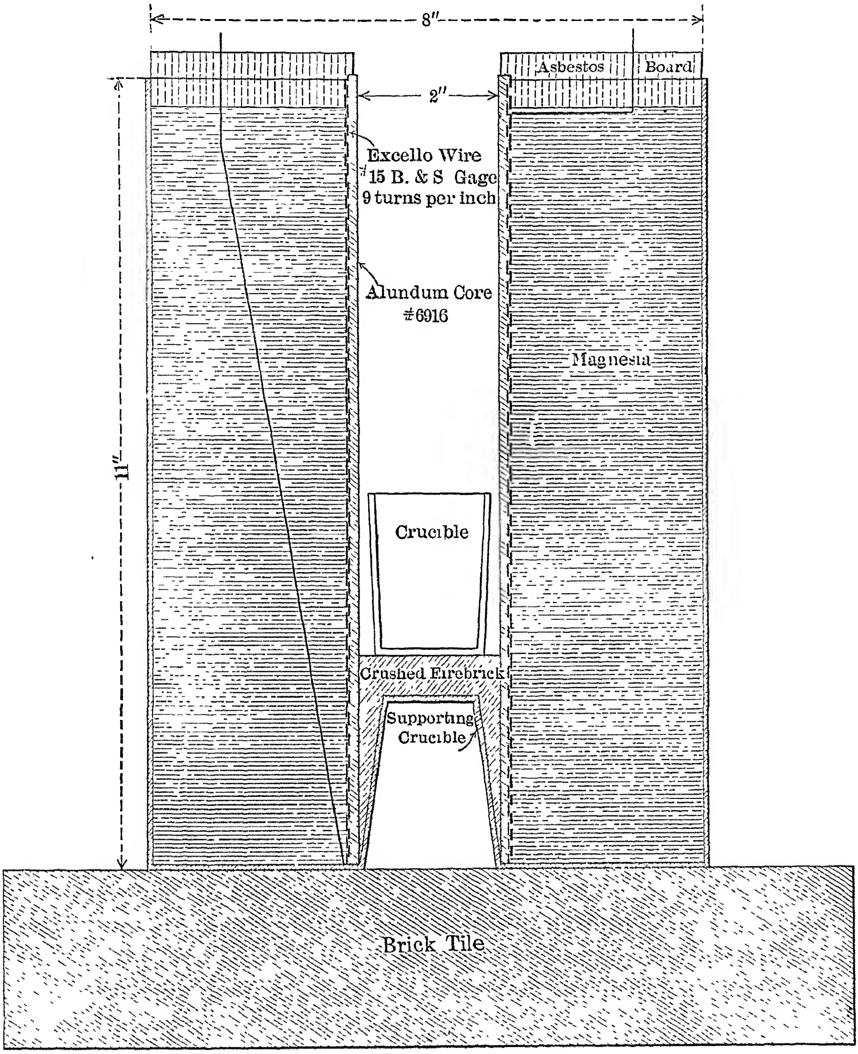

Fig. 2.—Electric Furnace.

a 0.5-in. hole drilled through the bottom, was placed as shown at *A*. Bricks were placed below the grate bars as shown at *C* in order to support a "Denver B" crucible as shown at *D*.

A coke fire was built on the grate around the crucibles *A* and *B*. The nickel cathode was cut into strips by power shears and these strips were

placed in the crucible *A*. When a temperature of about 1,000° was attained the cover of the crucible was removed, some stick sulphur thrown in and the cover replaced. Some nickel sulphide was formed and flowed out through the hole in the bottom of crucible *A* into crucible *D*. This procedure was repeated at short intervals until practically all the metallic nickel was converted to sulphide.

The crucibles were next removed from the furnace. When cool, the sulphide was removed, broken to pea size, mixed with about 15 per cent. of its weight of sulphur and remelted in a graphite crucible. The crucible containing the sulphide was set in a larger crucible and the space between filled with charcoal, in order to assure a reducing atmosphere. When the sulphide was melted, it was covered with charcoal and kept at about

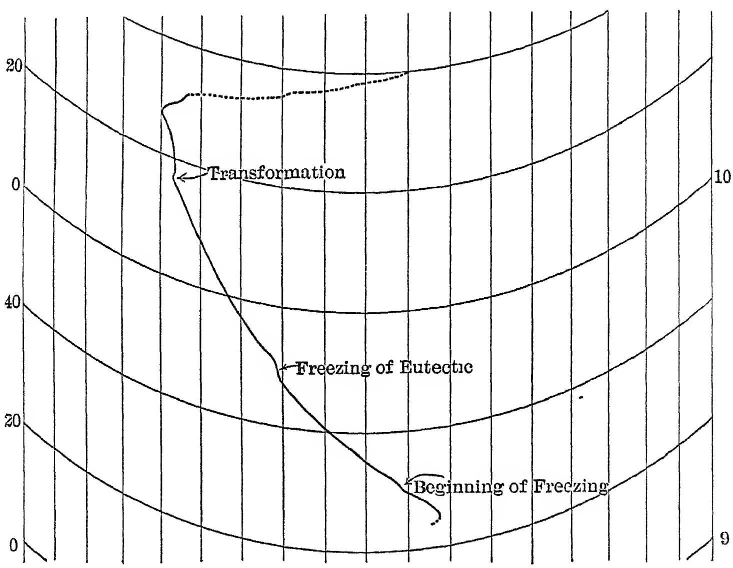

Fig. 3.—Cooling Curve for 50 Cu_2S, 50 Ni_3S_2.

1,000° C. for 35 hr. in periods of about 8 or 9 hr. each. There was no reason for heating intermittently, but the coke fire was allowed to burn out over night.

After 12 hr. of fusion the material contained 69.87 per cent. Ni; after 20 hr., 72.25 per cent. Ni. The final product had the following composition: Ni(Co), 72.45; Fe, 0.53; insoluble (SiO_2), 0.30; S (by difference), 26.72 per cent. The rational analysis of the sulphide calculated on the above basis is therefore

$Ni_3S_2(Co_3S_2)$	98.87
FeS	0.83
Insoluble	0.30
Total	100.00

Furnace.—The sketch of the furnace used for determining the cooling curves is shown in Fig. 2 and is self-explanatory. It was connected to the 110-volt circuit in series with two rheostats for controlling the temperature. A current of 10 amperes was sufficient to produce a temperature of 1,200° C. in 30 min.

Pyrometer.—The temperatures were measured by a Pt-Pt.Rh couple connected to a Siemens & Halske recording galvanometer. This instrument draws a cooling curve consisting of a series of dots imprinted by a pointer attached to the galvanometer needle as it is automatically pressed every 15 sec. on a paper moved by clock work over an inked ribbon. Fig. 3 shows a typical curve made by this instrument.

The pyrometer was calibrated in the usual manner with the cold junction in a bath of melting ice. The following results were obtained:

	Temperature. Degrees C.	Deflection. Millivolts.
Melting point of ice	0	0.00
Boiling point of water	100	0.40
Boiling point of naphthalene	218	1.20
Boiling point of sulphur	444	3.33
Freezing point of aluminum	657	6.02
Freezing point of sodium chloride	800	8.02
Freezing point of silver	961.5	10.57
Freezing point of copper	1,084	12.72

Determination of Cooling Curves.—Charges weighing 60 g. were used in all cases except where only a slight retardation point was indicated, in which instances 100-g. charges were used. The fusions were made in No. 00 graphite crucibles with a charcoal covering to prevent oxidation of the charge. The junction was protected by a fused silica tube. In order to be certain that the entire charge was melted it was found necessary to heat each test above 1,100°. Two cooling curves and one heating curve were obtained for each mixture, and in cases where points were in doubt three or more were obtained.

In nearly all cases the instrument recorded sharply the beginning of freezing and the other retardation points. These deflections were carefully scaled on the record paper and the corresponding temperatures obtained from the calibration plot. The results are given in the table on the following page.

In none of the tests here recorded was the record taken below 600°. When the work was nearly completed, however, it was recalled that Bornemann[2] had recorded a transformation in Ni_3S_2 between 527° and 538°. The cooling curves for the samples with 100, 75, 50, 10, and 2.5 per cent. of Ni_3S_2 were therefore re-determined and a lower point was found at 546°, 532°, 532°, 531°, and 525°, respectively. This seems to indicate that it is probably present in the other mixtures.

[2] *Metallurgie*, vol. v, No. 1, p. 13 (Jan. 8, 1908); vol. vii, No. 21, p. 667 (Nov. 8, 1910).

Per Cent. Cu_2S.	Per Cent. Ni_3S_2.	Recorded Retardations. Degrees Centigrade.	
100.0	0.0	1,130	
97.5	2.5	1,086	
95.0	5.0	1,068	
90.0	10.0	1,043	727
80.0	20.0	1,008	728
70.0	30.0	982	731
60.0	40.0	953	731
50.0	50.0	925	729
40 0	60.0	884	728
30.0	70.0		727
30.0*a*	70.0	820	726
27.5*a*	72.5	798	726
25.0*a*	75.0	773	728
20.0	80.0	727	
20.0*a*	80.0	726	
10.0	90.0	739	(728)*b*
5.0*a*	95.0	768	(740)*b*
0.0	100.0	794	

a 100-gram charge. *b* End of freezing.

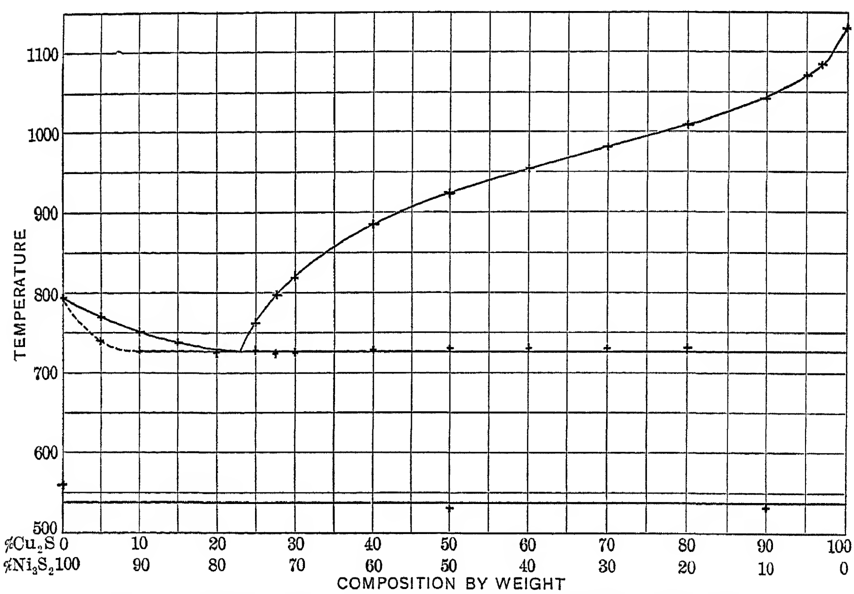

FIG. 4. —EQUILIBRIUM DIAGRAM OF THE SYSTEM Cu_2S-Ni_3S_2.

Equilibrium Diagram.—The equilibrium diagram plotted from the above figures is shown in Fig. 4. It is of the typical underscored-V type and is self-explanatory. The position of the eutectic point and the ends of the eutectic line were established by further tests, as described later.

Photomicrographs.—After determining each cooling curve, a piece of

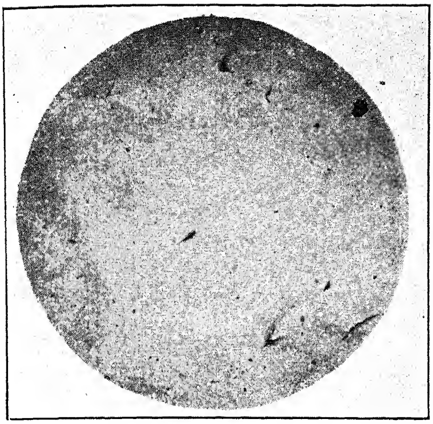

FIG 5.—Ni_3S_2.

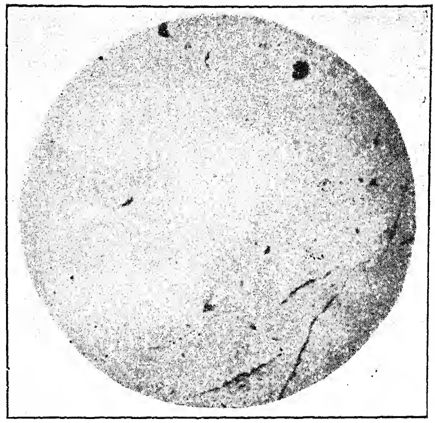

FIG. 6.—5 Cu_2S, 95 Ni_3S_2.

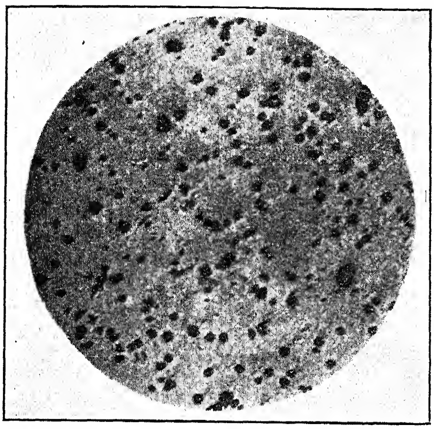

FIG. 7.—10 Cu_2S, 90 Ni_3S_2.

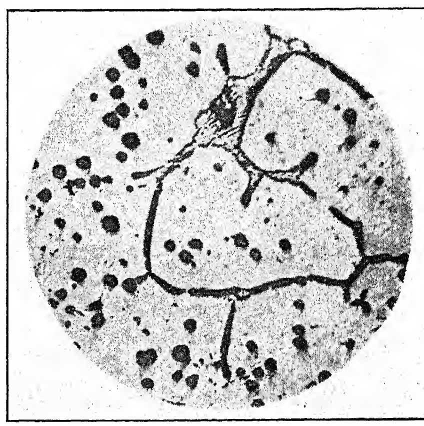

FIG. 8.—15 Cu_2S, 85 Ni_3S_2.

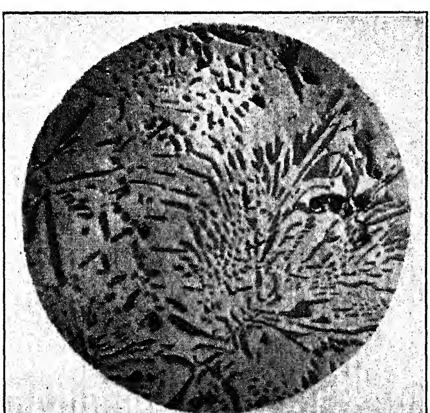

FIG. 9.—20 Cu_2S, 80 Ni_3S_2.

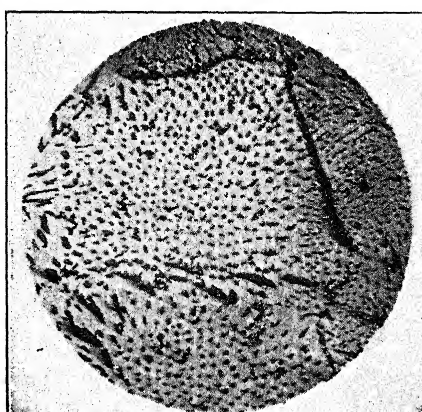

FIG. 10.—23 Cu_2S, 77 Ni_3S_2.

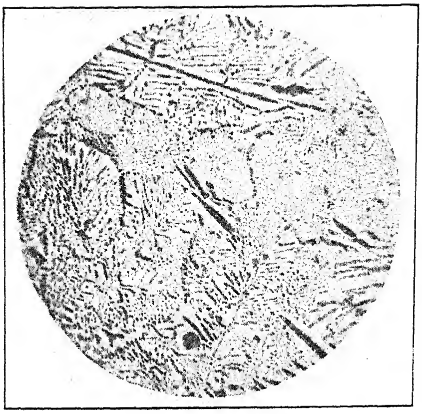

FIG. 11.—EUTECTIC RAPIDLY COOLED BUT NOT CHILLED.

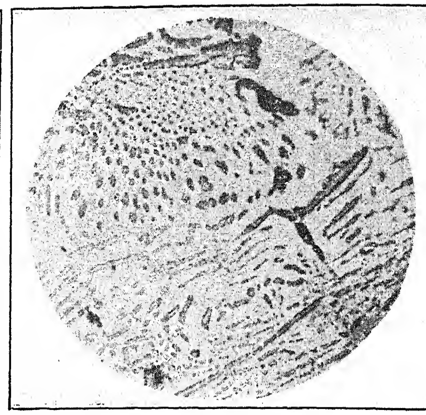

FIG. 12.—25 Cu_2S, 75 Ni_3S_2.

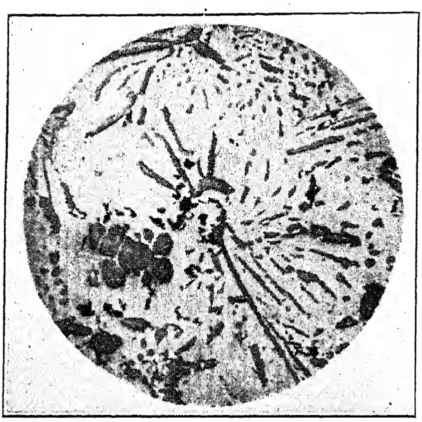

FIG. 13.—30 Cu_2S, 70 Ni_3S_2.

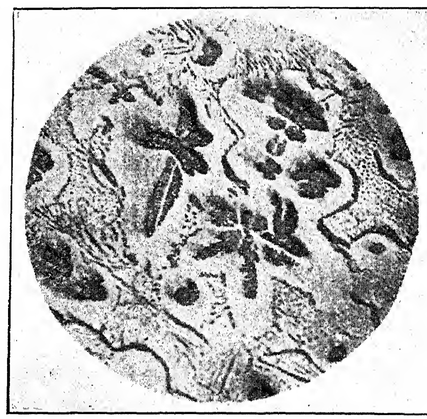

FIG. 14.—30 Cu_2S, 70 Ni_3S_2. COOLED RAPIDLY BUT NOT CHILLED.

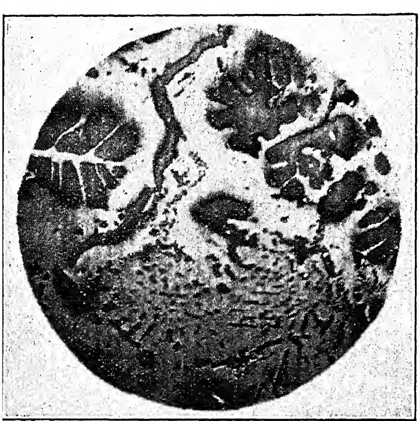

FIG. 15.—40 Cu_2S, 60 Ni_3S_2.

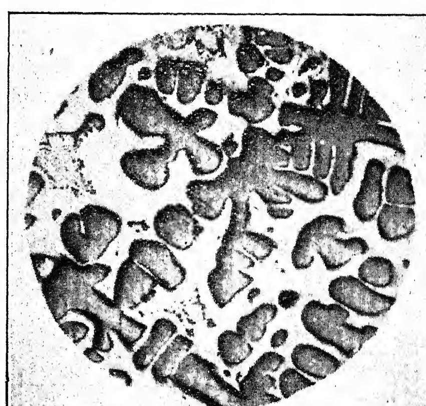

FIG 16.—50 Cu_2S, 50 Ni_3S_2.

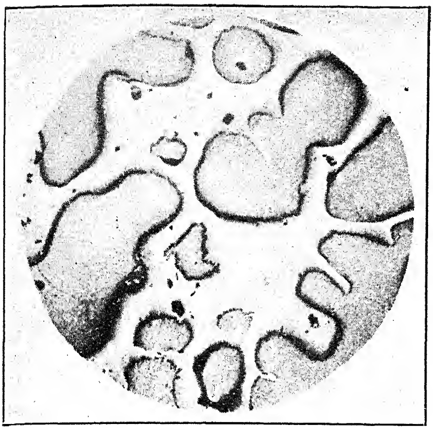

FIG. 17.—60 Cu_2S, 40 Ni_3S_2.

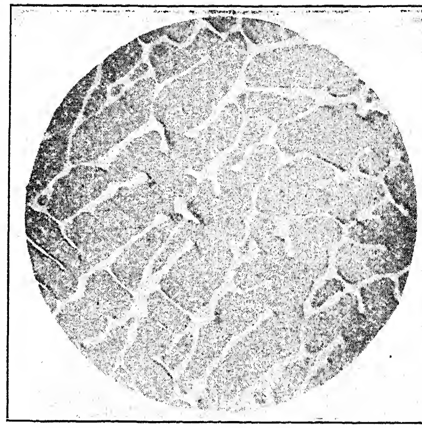

FIG. 18.—70 Cu_2S, 30 Ni_3S_2.

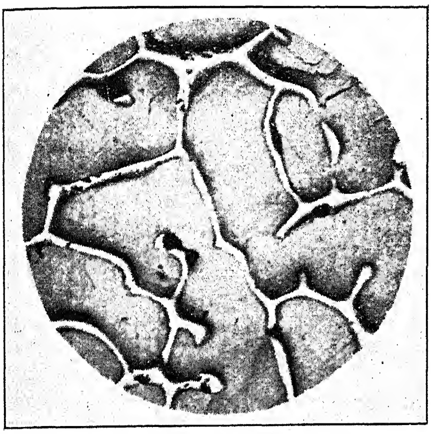

FIG. 19.—80 Cu_2S, 20 Ni_3S_2.

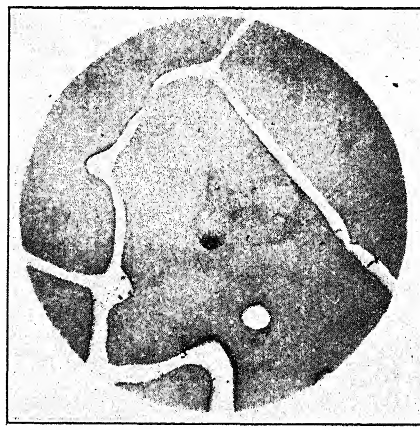

FIG. 20.—90 Cu_2S, 10 Ni_3S_2.

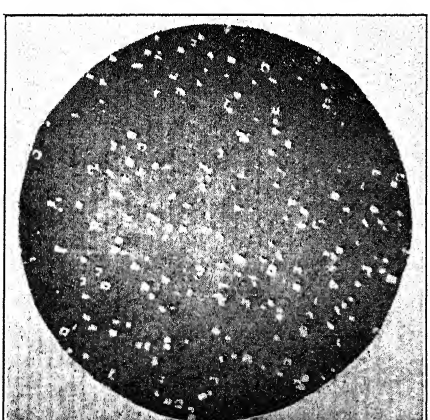

FIG. 21.—95 Cu_2S, 5 Ni_3S_2.

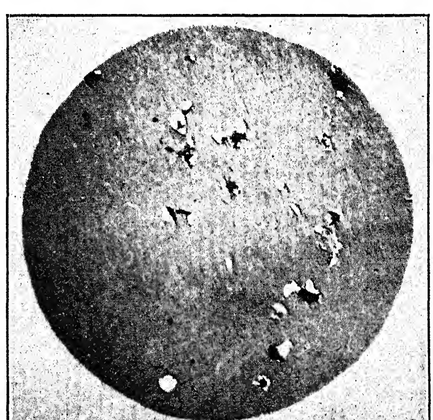

FIG. 22.—97.5 Cu_2S, 2.5 Ni_3S_2.

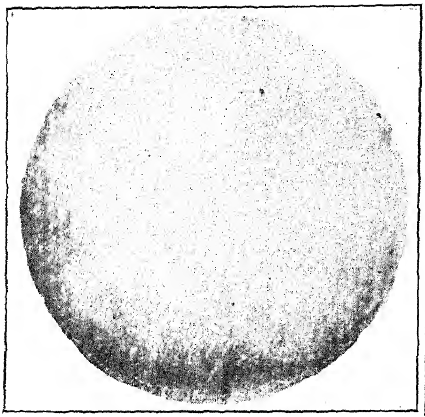

FIG. 23.—Cu_2S.

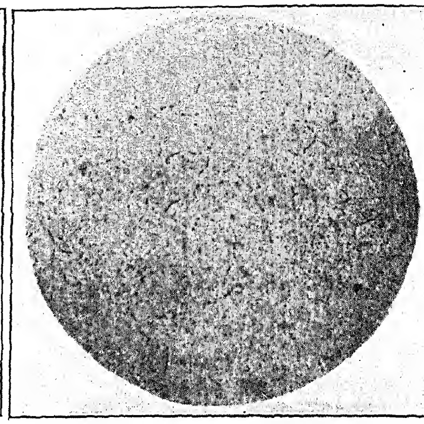

FIG. 24.—10 Cu_2S, 90 Ni_3S_2. CHILLED.

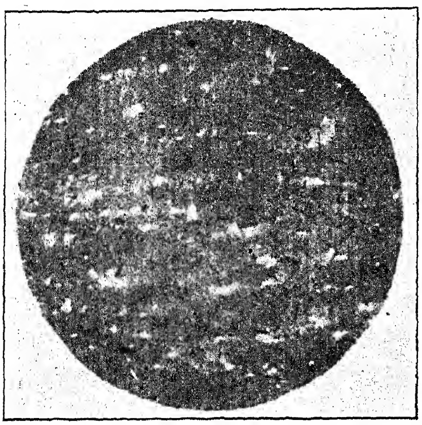

FIG. 25.—20 Cu_2S, 80 Ni_3S_2. CHILLED.

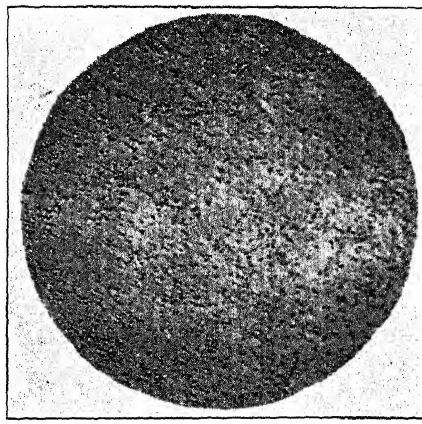

FIG. 26.—20 Cu_2S, 80 Ni_3S_2. CHILLED, REHEATED.

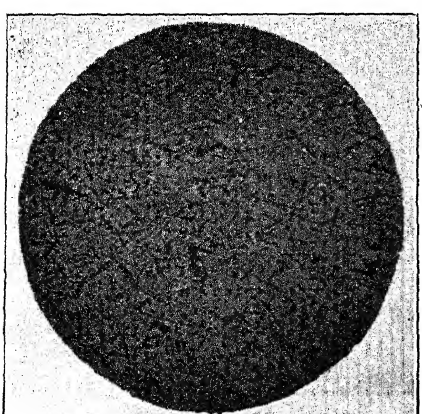

FIG. 27.—30 Cu_2S, 70 Ni_3S_2. CHILLED.

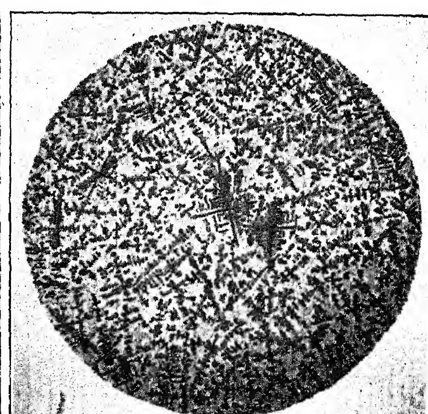

FIG. 28.—40 Cu_2S, 60 Ni_3S_2. CHILLED.

the matte was polished and studied under the microscope. In the unetched specimens two constituents were observed, one pale brass and the other pale blue color. The former appears light gray in the photograph and the latter dark gray. These two constituents resemble in general pure Ni_3S_2 and pure Cu_2S, respectively, but are slightly darker in each case. It is probable that the lighter constituent is Ni_3S_2 with a small amount of Cu_2S in solution and that the darker constituent is Cu_2S with a small amount of Ni_3S_2 in solution. Actual measurements of the light and dark areas were made on several photographs, and, although check results were not obtained, it was found that they were roughly proportional to the amounts of Ni_3S_2 and Cu_2S in the sample. In the following discussion the light, or nickel-rich, constituent will be designated as α and the dark, or copper-rich, constituent will be designated as β. Etching with concentrated and dilute acids resolved the large β areas into grains, but failed to reveal anything further. Photomicrographs of the unetched specimens, magnified in all cases 60 diameters, are given in Figs. 5 to 28. A study of the series shows a eutectic structure beginning with 15 per cent. Cu_2S, becoming more marked with 20 per cent. Cu_2S, reaching a maximum with 23 per cent. Cu_2S, and then diminishing. In the photographs of specimens containing more than 60 per cent. Cu_2S the eutectic structure has disappeared. The cooling curves, however, showed a pronounced retardation at the eutectic line, so it is probable that the typical eutectic structure has been obliterated by segregation of the constituents. This segregation is not surprising in view of the wide difference in temperature between the point where freezing begins and the eutectic line.

Some of the photographs show irregular black spots due to cracks or pits in the specimens.

Special Tests.—The mixture containing 20 per cent. Cu_2S, as seen in the table, gave only one retardation point, which was at the eutectic line. The microscopic examination, however, indicated a slight excess of Ni_3S_2, so a mixture with 23 per cent. Cu_2S was prepared, which, as seen in the photograph, is practically all eutectic. The eutectic point is accordingly placed at this composition.

The specimen with 10 per cent. Cu_2S showed no retardation at the eutectic line, but the photograph shows dots of β. In order to see if this β had separated in the solid state, the sample was remelted and the crucible was set in ice water just after the eutectic temperature was passed in cooling. The photograph of a polished section is shown in Fig. 24. Fine dots of β are seen, but the general appearance of the photograph indicates that a more rapid chilling of the specimen would have prevented the separation.

Since, therefore, the sample with 15 per cent. Cu_2S shows eutectic and the sample with 10 per cent. Cu_2S, as shown above, is probably a solid

solution when freezing is completed, the limit of the eutectic line falls between these two compositions. In the diagram it is drawn nearly to 10 per cent. Cu_2S, which is approximately correct. The opposite end of the eutectic line was fixed at 97.5 per cent. Cu_2S by a similar experiment.

Fig. 25 shows the structure of a chilled specimen of the matte with 20 per cent. Cu_2S. While the matte was still molten the crucible was removed from the furnace and the contents were poured into an iron mold. Fig. 26 shows the structure of the same specimen after annealing at 650° C. for a few minutes and cooling slowly. This specimen shows clearly the β crystals which have formed in the solid matte. Figs. 27 and 28 show respectively the structure of the matte with 30 and 40 per cent. Cu_2S, cast in an iron mold. It indicates that the β constituent originally forms as small dendrites and that the characteristic coarse structure of the slowly cooled specimens is due to the growth and segregation of these crystals.

Several tests were made to see if there was any tendency toward layering while the matte was liquid. For this purpose a 0.5-in. hole 5 in. deep was bored in a section of a 1-in. graphite rod, thus making a tall, narrow crucible. The matte was melted in this and held for 2 hr. in a molten condition (800°), after which it was cooled in the furnace and sections near the top and bottom were examined under the microscope. In all cases there was slightly more eutectic visible in the lower section, but this was probably due to the fact that the eutectic had melted first and flowed to the bottom.

A series of specific gravity tests was planned, but was abandoned because it was discovered that the specific gravities of the two sulphides were very nearly the same. The values were approximately: Cu_2S, 5.76; Ni_3S_2, 5.84.

Summary

The results of this work may be summarized as follows:

1. Nickel sulphide of approximately the composition NiS when molten, gradually loses S until the composition Ni_3S_2 is reached, at which point it remains stable. This confirms the work of Bornemann.

2. The series Ni_3S_2–Cu_2S is eutectiferous between 2.5 and 90 per cent. Ni_3S_2. Outside of these ranges there is a series of solid solutions.

3. The eutectic point was found at 77 per cent. Ni_3S_2.

4. The freezing point of Ni_3S_2 was found to be 794° C.; Cu_2S, 1,130° C.; and the eutectic, 728° C.

5. No evidence of chemical compounds between the two sulphides was discovered.

The Work of Crushing

BY ARTHUR F. TAGGART,* NEW HAVEN, CONN.

(New York Meeting, February, 1914)

A GENERAL awakening of interest among mill men concerning the mechanical efficiencies of their crushing machines is evident from a perusal of the recent files of mining publications. Considering the large part of the power bill which must be debited to the crushing department, such interest is natural. When, however, the articles on the subject are read, the only statement upon which the writers agree is that fine grinding consumes a large amount of power, and that the machine which, from a concentration standpoint, offends as a slime producer is, for that reason, a serious offender in wasting power. When the mill man attempts to find a method for measuring the power wasted, or to compare the efficiency of one machine with that of another for the same work, he is confronted with a choice of methods which lead to conflicting results.

There are two reasons why the work of crushing is not more generally understood. In the first place, experimental data are difficult to obtain; and in the second place, before these data can be put in general form certain assumptions must be made. A difference in these assumptions by different investigators has led to conflicting conclusions. This conflict has resulted in the proposal of two laws. The first of these is the so-called Rittinger's law, which is variously stated as follows:

"The work of crushing is proportional to the reduction in diameter."—R. H. Richards: *Ore Dressing*, p. 304 (1903).

"The work required to crush rock is very nearly proportional to the reciprocals of the diameters crushed to."—A. Del Mar: *Engineering and Mining Journal*, vol. xciv, No. 24, p. 1129 (Dec. 14, 1912).

"The work done in crushing is proportional to the surface exposed by the operation, or better expressed for this purpose, the work done on a given mass of rock is proportional to the reciprocal of the diameter of the final product, assuming that all the mass has been reduced to one exact size, which is only theoretically possible."—A. O. Gates: *Engineering and Mining Journal*, vol. xcv, No. 21, p. 1039 (May 24, 1913).

Of this law as variously stated above H. Stadler says (Grading Analyses and Their Application, Author's Reply to Discussion, *Transactions of the Institution of Mining and Metallurgy*, vol. xx, p. 426 [1910–11]):

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". . . . . . many mining engineers still have blind faith in an old blunder which, under the name of Rittinger's law, has been thoughtlessly reprinted and carried on in edition after edition of mining books since the days of the 'Dark Ages' (1850). This 'law' is a myth which has never been recognised by science, and it is unfair to Rittinger's memory to connect his name with what is clearly nonsense, the currency of which, in the mining world, is due either to misunderstanding or the error of a translator. All that Rittinger himself really said on the laws of crushing, in his famous book on ore-dressing, fills barely two out of about 600 pages, and in these two pages he says clearly: '*the increase of the surfaces exposed is directly proportional to the force required for reducing.*' (These words are also in the original text printed in italics.) As Rittinger goes on to say: 'and therefore also to the work absorbed in effecting the separations,' it may certainly be taken for granted that he supposed the force acting in the fracture planes themselves. Now, this may be conceivable for chemical, electrical, thermal actions and reactions, but not for external forces as applied in mechanical crushing. . . . Had Rittinger stated that the increase of surface is proportional both to 'force' and to 'work done,' he would have been guilty of mistaking 'force' and 'work done' as identical. Rittinger's law, therefore, simply states the proportion of the increase of surface to the *force* required in crushing and not also to the *energy* absorbed, which, in conformity with Kick's law, varies as the volumes."

Kick's law is stated as follows:

"The energy required for producing analogous changes of configuration of geometrically similar bodies of equal technological state varies as the volumes or weights of these bodies."—H. Stadler: Grading Analyses and Their Application, *Transactions of the Institution of Mining and Metallurgy*, vol. xix, p. 478 (1910–11).

The writer has made a careful analysis of the proofs of the previously quoted authors and has come to the conclusion that the work of crushing is proportional to the volumes of the particles crushed, according to Kick's law; and not to the new area produced, as stated in Rittinger's "law." The reasons for this conclusion follow.

Kick's law is unquestionably correct for all substances where the changes of configuration are within the elastic limit. For perfectly elastic substances the statement holds true to final rupture, and for substances almost perfectly elastic, such as rock, the law is a very close approximation of the fact.

The behavior of structural materials under stress has been widely investigated. The accompanying phenomena are well understood and the laws controlling them are universally accepted. Briefly stated, these laws are:

Within the elastic limit of any substance the force required to produce a given deformation is directly proportional to the area of the transverse section.

The amount of deformation within the elastic limit is directly proportional to the length of the specimen and to the force applied.

The work done in producing a given deformation is the product of the average force by the distance through which it acts.

These laws apply both in tension and in compression.

If, now, we examine the behavior under stress of some highly elastic substance, the results of the examination can be plotted according to the following characteristic curves:

Fig. 1 is a force-area diagram for a given deformation within the elastic limit of the substance. The straight line represents, of course, the direct proportion between transverse area and the force required to produce deformation.

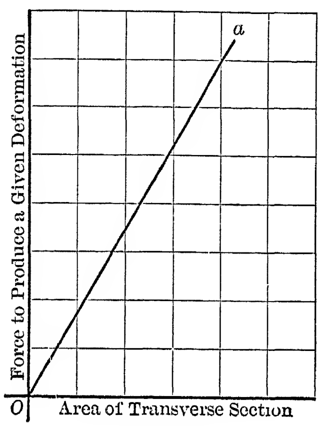

FIG. 1.

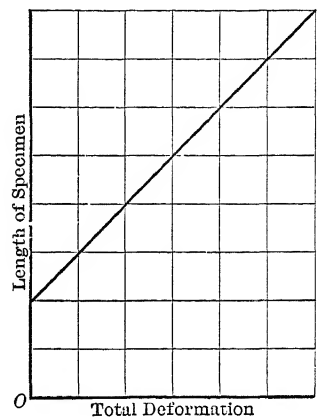

FIG. 2.

Fig. 2 represents the relation, within the elastic limit, between length of specimen and total deformation under a given load. The straight line is here the graphical representation of the law that the deformation under load is, within the elastic limit, directly proportional to the length of the specimen.

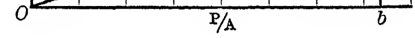

FIG. 3.

The phenomena represented by these curves are typical of all elastic substances both in tension and in compression.

Fig. 3 gives the force-deformation diagram for a highly elastic substance. The portion of the curve, Oa, represents the behavior of the material within the elastic limit. This portion being a straight line, the conclusion is that deformation is directly proportional to the force exerted, through this portion of the curve. The point a marks the elastic limit of

the material. The point *d* marks final rupture. From *a* to *d* unit deformation increases much more rapidly than unit stress. The total work per unit of volume to produce rupture is the area *Oadb*.

The preceding statements may be mathematically expressed as follows:[1]

Within the elastic limit

$$f = \frac{PL}{AE}$$

$$W = \frac{Pf}{2} = \frac{P^2L}{2AE} = \frac{A^2S^2L}{2AE} = \frac{S^2}{2E} \times AL$$

When $$\frac{P}{A} = S$$

If, to simplify the mathematics of the demonstration, we assume the particle under load a cube of edge D, then $A = D^2$, $L = D$, S^2/E is an assumed constant, and

$$W = \frac{S^2}{2E} \times D^3$$

or the work of deformation is proportional to the volume of the particle deformed.

For the maximum unit stress within the elastic limit

$$W = \frac{e^2}{2E} \times AL$$

or the work of deformation, at the elastic limit, is proportional to the volume of the particle deformed.

It is evident from the curve, Fig. 3, that the nearer to *a* rupture occurs, the greater the ratio of work done within the elastic limit will be to the total work necessary to produce rupture. If a substance fractured imme-

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[1] The following notation applies throughout the mathematical discussion unless otherwise noted:

W = Work.
e = Maximum unit stress within the elastic limit.
f = Deformation.
L = Length of body.
A = Area of transverse section.
S = Any unit stress within the elastic limit of the substance.
P = Units of force.
D = Edge of original or unit cube. The cube is chosen for the shape of the particle under discussion for the purpose of simplifying the mathematical development.
U = Ultimate unit stress to produce fracture.
n = Any number.
d = Edge of smaller cubes resulting from crushing.
E = Modulus of elasticity.

diately on reaching its elastic limit, the work would be represented directly by the formula

$$W = \frac{e^2}{2E} \times AL$$

The more highly elastic the substance, the more closely does the work done in rupture approximate the above formula. Thus for highly elastic

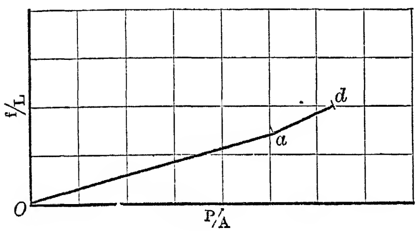

FIG. 4.

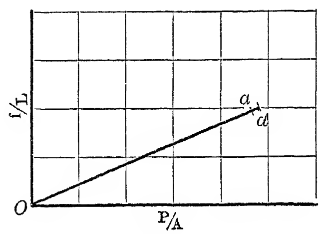

FIG. 5.

steels the force-deformation diagram is as shown in Fig. 4, and for hard rock the diagram becomes as shown in Fig. 5.

The conclusion, then, is forced upon us that the work of crushing a piece of rock is very closely represented by the formula

$$W = \frac{e^2}{2E}AL$$

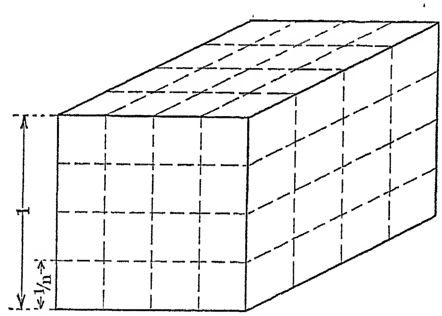

FIG. 6.

If we examine the proofs of Del Mar, Gates, and Professor Richards we find that the distance factor is neglected and that the formula for work takes the form

$$W = KP$$

where W represents units of work, K is a constant, and P represents the average force required to produce rupture.

Thus Professor Richards's proof (*Text Book of Ore Dressing*, p. 167) is essentially as follows:

The number of planes of fracture of area one necessary to divide a cube (Fig. 6) of edge one along "n" planes parallel to a face of the cube is $n - 1$, and to divide the unit cube into n^3 smaller cubes of equal size requires fracture along $3(n - 1)$ planes of area one. If the work done to produce fracture along one plane of area one is B, then the work to divide the cube of edge one into n^3 smaller cubes of edge $\frac{1}{n}$ will be $3B(n - 1)$. Here the error creeps in. Professor Richards says further: "Applying this to any cube where D is the diameter of the original cube and d the diameter of the smaller resulting cubes in linear units, n becomes $\frac{D}{d}$. In making one cut through this cube, the area of fracture would be D^2 and our formula now becomes, $3BD^2\left(\frac{D}{d} - 1\right)$." [In the original notation A takes the place of B in the formulæ.]

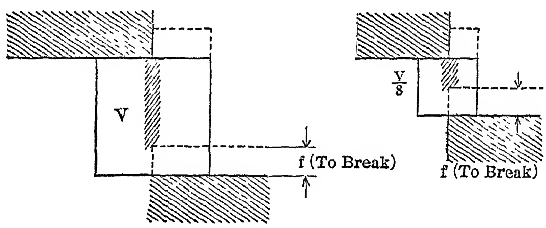

FIG. 7.

This can be true only if "force" and "work done" are identical. While it is true that the work done in producing fractures aggregating D^2 in area will be $3BD^2\left(\frac{D}{d} - 1\right)$ if the work is done separately on D/1 cubes of edge one, it is not true that the work to produce a fracture of area D^2 in a cube of edge D will be $3BD^2\left(\frac{D}{d} - 1\right)$. The original assumption that B equals the work to produce a fracture of area one from a cube of edge one is true only if $B = \frac{e^2AL}{2E}$ (assuming the rock perfectly elastic). In the particular case assumed, where the edge of the cube is taken as one, $B = \frac{e^2(1)^3}{2E} = \frac{e^2}{2E}$ and the volume relation is lost sight of; but when the edge of the cube is assumed to be D, the work to produce fracture along a plane of area D^2 is $\frac{e^2D^3}{2E}$, and the total work required to reduce the cube of

edge D to $(D/d)^3$ cubes of edge d is $\frac{3e^2}{2E}D^3\left(\frac{D}{d} - 1\right)$, or the work is proportional to the volumes of the original and resulting cubes.

Gates recognizes the distinction between "work done" and "force required to do the work" and starts out with the statement:[2]

$$\text{Energy} = S'F'f$$

when applied to the theoretical cases illustrated in Fig. 7, where S' is the average resistance to shear per square inch, F' is the area of fracture for one break parallel to a face in a cube of volume V, $F'/4$ is the area of fracture for one break in a cube of volume $V/8$, and f is the distance moved through by the crushing faces to produce fracture. Gates admits that within the elastic limit of the substances, f is equal to a constant times the thickness (or diameter) of the body and hence that work to compress varies as the volume of the body, but he says further, when the forces are applied until rupture occurs:

"To break the molecular bond between adjacent particles would require the same movement regardless of the thickness of the piece."

". . . . . it will not be hard to see that the distance through which the offset faces must move in either case must be the same and not proportional to the thickness of the piece."

If Gates intends to say that the forces applied by a crushing machine are such as to produce shearing stresses of the kind he represents, he is clearly wrong. If, on the other hand, the case is one of compression between two crushing faces, and we follow his statements through to their logical extreme, we will find that a deformation which is within the elastic limit, when a cube of rock of one thickness is compressed, is greater than the thickness of some other cube. It will follow, then, that with a movement of the crushing faces equal to the thickness of the smaller piece we will admittedly cause rupture of the smaller piece, while with the same movement the deformation of the larger piece will be within the elastic limit and no rupture will occur. To cite a specific instance, let us assume two cubes of magnesian limestone, the larger 8 in. on an edge and the smaller 0.0025 in. on an edge. Trautwine (*Engineer's Pocket Book*, 18th ed., p. 923) cites the result of a test by Capt. James B. Eads showing that a column of magnesian limestone 8 in. high and 2 in. in diameter shortened 0.0025 in. under pressure and recovered when relieved. If, then, we subject both of the above cubes to a crushing force which shall act through a distance of 0.0025 in., the small piece will be crushed, the large piece will not be ruptured, and the fallacy of Gates's argument will be made apparent.

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[2] *Engineering and Mining Journal*, vol. xcv, No. 21, p. 1040 (May 24, 1913).

If we examine the two proofs just analyzed from another standpoint, starting with the fundamental equations

$$f = \frac{PL}{AE}$$

and

$$W = \frac{Pf}{2} = \frac{P^2L}{2AE}$$

if P and E are constant

$$W = \frac{KL}{A} \quad (K = \text{Constant} = P^2/2E)$$

or for a cube

$$W = \frac{KD}{D^2} = \frac{K}{D}$$

and the work done in producing a given deformation within the elastic limit is proportional to the reciprocal of the diameter of the particle deformed, which is the conclusion reached by Gates and Professor Richards.

But in no crushing machine in actual operation in the mills is the force exerted the same on pieces of all sizes. Hence the assumption that P is a constant is erroneous, and the conclusion drawn is likewise erroneous.

Before proceeding to a consideration of Del Mar's argument in support of Rittinger's law, an understanding of Stadler's method of application of Kick's law is necessary. In his paper Grading Analyses and Their Application, Stadler says:

"The volumes of the particles decrease from grade to grade at the same ratio as the number of particles, constituting in their total the volume of the unity, increases, and the product of the volumes into the number of the particles of that grade is, therefore, constant for each grade. As in conformity to the above law, the amount of energy absorbed is proportional to the volume of the body to be crushed, it follows again also that the total energy required for reducing the weight of the unit *is constant for each grade.*

"The ordinal numbers of any arithmetical progression given to these grades represent consequently the relative values of the energy which has to be spent upon producing this respective grade from the initial unit, or the *mechanical value* of the grade.

"For obtaining the *mechanical value of mixed sands,* we need only to multiply the percentages of the gradings by the number of the energy units of the respective grade and add the products. This possibility of having the gradings of pulps condensed and expressed in *one representative figure* proves to be of great value.

"The *useful work done per unit* by any crushing machine is determined by the difference between the mechanical values of the samples, taken at the inlet and the discharge of the machine, and for obtaining the *total work done* this difference has to be multiplied by the tonnage dealt with.

"The *relative mechanical efficiency* is the value obtained by dividing the total work done by the unit of energy (for instance, HP.):

Relative mech. efficiency =

$$\frac{\text{Tonnage} \times \text{Work done per unit in E. U."}}{\text{Unit of Energy (HP.)}}$$

The use of the ordinal numbers or E. U. is illustrated in subsequent tables quoted from Del Mar's article.

Del Mar attacks the problem by means of the "deadly parallel." Taking grading analyses showing the results of three crushing tests, he computes the relative mechanical efficiencies according to the method of volumes (Stadler's method) and to the method of areas exposed by crushing. In applying this latter method Del Mar assumes the relative energy unit for each grade as the reciprocal of the average size of particle in the grade. The calculations, taken from Del Mar's article,[3] follow:

CASE I

TABLE I.—*Screen Analyses of Mill Material*

Mesh	Mill No. 1		Mill No. 2	
	Mill feed %	Discharge %	Mill feed %	Discharge %
On 20	3.1	....	15.1	3.5
On 40	15.5	3.2	35.6	21.2
On 60	15.6	4.5	10.4	14.1
On 80	14.6	10.5	11.1	17.9
On 100	9.6	15.8	6.4	11.2
On 120	2.4	2.4	0.7	1.6
Through 120	39.2	63.6	20.7	30.5

TABLE II.—*Efficiency of Mill No. 1*

Mesh	Reciprocal of average size	Feed %	Relative surface in feed	Discharge %	Relative surface in discharge
+20	26.5	3.1	82	....	....
+40	41.4	15.5	641	3.2	132
+60	83.6	15.6	1,304	4.5	376
+80	138	14.6	2,015	10.5	1,449
+100	163	9.6	1,564	15.8	2,575
+120	204	2.4	489	2.4	489
−120	253	39.2	9,917	63.6	16,090
Units of work in feed			16,012	Units of work in disch.	21,111
Units of work in feed					16,012
Difference, units of work done					5,100

[3] *Engineering and Mining Journal,* vol. xciv, No. 24, p. 1129 (Dec. 14, 1912).

TABLE III.—*Efficiency of Mill No. 2*

Mesh	Reciprocal of average size	Feed %	Relative surface in feed	Discharge %	Relative surface in discharge
+20	26.5	15.1	400	3.5	92
+40	41.4	35.6	1,473	21.2	877
+60	83.6	10.4	919	14.1	1,178
+80	138	11.1	1,532	17.9	2,470
+100	163	6.4	1,043	11.2	1,825
+120	204	0.7	143	1.6	326
−120	253	20.7	5,237	30.5	7,716
Units of work in feed			10,747	Units of work in disch.	14,484
Units of work in feed				. . . .	10,747
Difference units of work done				. . . .	3,737

"Mill No. 1 has done 5100 units of reduction with an output of $2\frac{1}{2}$ tons per hp. or $5100 \times 2\frac{1}{2} = 12,750$ units of reduction work, while mill No. 2 has done 3737 units of reduction with an output of three tons per horsepower or 11,211 units of reduction."

This shows an excess efficiency of mill No. 1 over mill No. 2 of 12.7 per cent.

TABLE IV.—*E. U. of Mill No. 1*

Mesh	E. U. average size	Feed %	E. U. feed	Discharge %	E. U. discharge
+20	14.2	3.1	44.0	. . . .	. . . .
+40	16.2	15.5	251.1	3.2	51.8
+60	19.2	15.6	299.6	4.5	86.4
+80	21.0	14.6	306.6	10.5	220.5
+100	22.0	9.6	211.2	15.8	347.6
+120	22.8	2.4	54.7	2.4	54.7
−120	24.0	39.2	940.0	63.6	1526.4
Totals.	. . . .	. . . .	2108.0	. . . .	2287.4

TABLE V.—*E. U. of Mill No.* 2

Mesh	E. U. average size	Feed %	E. U. feed	Discharge %	E. U. discharge
+20	14.2	15.1	214.4	3.5	49.7
+40	16.2	35.6	576.7	21.2	342.4
+60	19.2	10.4	199.6	14.1	270.7
+80	21.0	11.1	233.1	17.9	375.9
+100	22.0	6.4	140.8	11.2	246.4
+120	22.8	0.7	15.9	1.6	36.4
−120	24.0	20.7	496.8	30.5	732.0
Totals......	....	....	1877.3	....	.. 2053.5

"The first example, that of the two regrinding machines using the volume method, is worked out in Tables IV and V. For mill No. 1, this difference is 179 E. U. As the work done was 2½ tons per hp., this multiplied by 2½ will equal 447 E. U. For mill No. 2, the difference is 177.2. As the work done was three tons per horsepower, this multiplied by three equals 531 E. U. The work done by mill No. 2 is therefore 18% more than that done by mill No. 1, a direct contradiction of the relative efficiencies obtained by the reduction-in-diameter method."

CASE II

TABLE VI.—*Comparison of Single and Five-Stamp Units*

	Nissen stamp			5-stamp unit		
Mesh	Discharge %	Recip-rocal	Mechanical value	Discharge %	Recip-rocal	Mechanical value
+40	8.56	41.4	354	5.19	41.4	214
+60	13.92	83.6	1,163	13.75	83.6	1,149
+80	19.73	138.0	2,722	18.23	138.0	2,515
+100	3.40	163.0	554	3.21	163.0	523
+200	6.39	235.2	1,502	8.45	252.2	1,987
−200	43.39	400	17,356	48.82	400	19,528
Totals....	....	....	23,651	....	....	25,916

"The single unit is a Nissen stamp of 1659 lb., 7½-in. drop at 100 per minute crushing 5½ tons per stamp per day through a 40-mesh screen. The 5-stamp unit is a fast crushing design, 1250 lb., 7½-in. drop, 100 per minute, crushing 2.25 tons per stamp per day."

"The Nissen stamp has done 23,651 units of reduction with an output of $5\frac{1}{2}$ tons and an estimated expenditure of 4.44 hp. or

$$\frac{23{,}651 \times 5\frac{1}{2}}{4.44} = 29{,}200 \textit{ units of reduction}$$

while the 5-stamp mill has an output of 2.25 tons with 3.36 estimated hp., or

$$\frac{25{,}916 \times 2\frac{1}{4}}{3.36} = 17{,}300 \textit{ units of reduction}$$

The mechanical efficiencies are then as 1:0.59 in favor of the Nissen stamp. The compiler of the figures stated that the power consumption was 50% less for the Nissen stamp. The above figures more than bear this out."

TABLE VII.—*Comparison of Single and Five-Stamp Units*

	Nissen stamp			5-stamp mill	
Mesh	E. U. average size	Discharge %	E. U. discharge	Discharge %	E. U. discharge
+40	16.2	8.56	138.6	5.19	84.0
+60	19.2	13.92	267.2	12.75	264.0
+80	21.0	19.73	414.3	18.23	382.8
+100	22.0	3.4	74.8	3.21	70.6
+200	23.7	6.39	151.5	8.45	200.2
−200	26.0	43.39	1128.4	48.82	1269.3
Totals......	....	....	2174.8	....	2270.9

"Table VII shows the case of the Nissen stamps working in competition with the 5-stamp unit battery. The Nissen stamp has crushed $5\frac{1}{2}$ tons with an estimated horsepower of 4.44 or

$$\frac{2175 \times 5\frac{1}{2}}{4.44} = 26.94$$

while the 5-stamp unit has crushed $2\frac{1}{4}$ tons with 3.36 hp. or

$$\frac{2271 \times 2\frac{1}{4}}{3.36} = 15.2$$

The two mills then have done work in the ratio of 1:0.56, nearly the exact ratio found by the previous calculation, using the reduction by diameter.

"Having considered the case of crushing from an impartial standpoint, it has been found that in two cases[4] under review the results are nearly identical, while in one case they are the reverse. In the case where the volume method shows the recrushing mill No. 2 to have done better work than No. 1, the actual fact is that mill No. 1 does better work as shown by the reduction-of-diameter method."

The last statement is due to an error by Del Mar in the use of the term "relative energy" as defined by Stadler. The difference in E. U. as

[4] One case omitted.

developed by Del Mar (179 and 177.2 respectively) represents relative energy units per unit of weight, in this case the ton. The total relative work in each case is, then, the product of the relative work per unit of weight multiplied by the number of units of weight, or 13,425 and 13,215 respectively. This shows the relative work done in mill No. 1 greater than that in mill No. 2, as in Del Mar's method of calculation. The relative mechanical efficiencies obtained by the two methods are contradictory, as Del Mar remarks.

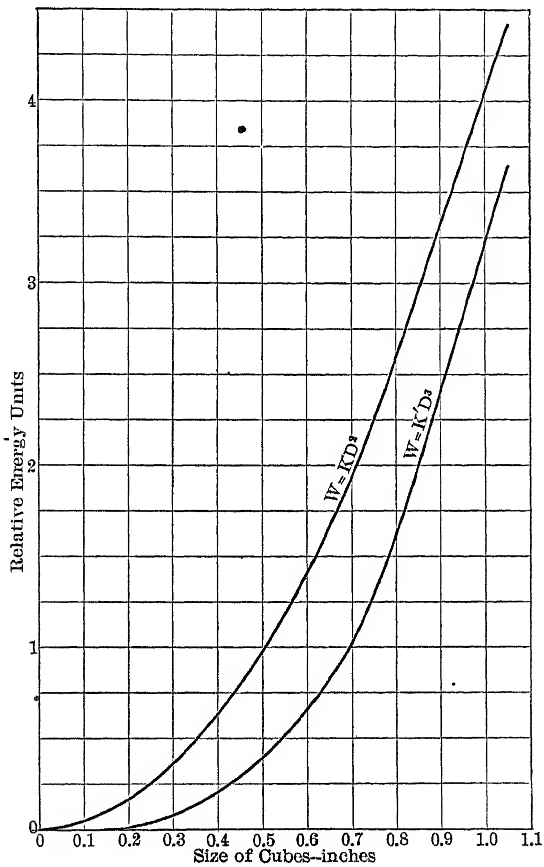

FIG. 8.

Part of the confusion that exists on this subject is due to the close agreement in the values of work over a certain range of the calculations under both methods. The reason for this apparent agreement is to be found in the graphs representing the two formulæ. The formula for work proportional to area of fracture is $W = KD^2$, which plotted gives a parabola. The formula for work proportional to volume is $W = K'D^3$, the graph of which is a cubical parabola.

In order to show the close agreement between these curves throughout a considerable range the ultimate unit stress per square inch to produce rupture in a highly elastic rock may be taken as 10,000 lb., and the deformation per inch of length from Eads's figure before cited as 1/3200 in. The volume formula then becomes

$$W = 3.13\ D^3$$

In order to bring the formula for work as advanced by Gates into as close agreement with this formula as possible it is assumed that in the case cited by Eads rupture would have taken place with a very slightly greater deformation than he gives, say 0.0004 in. per inch. The formula then becomes

$$W = 4D^2$$

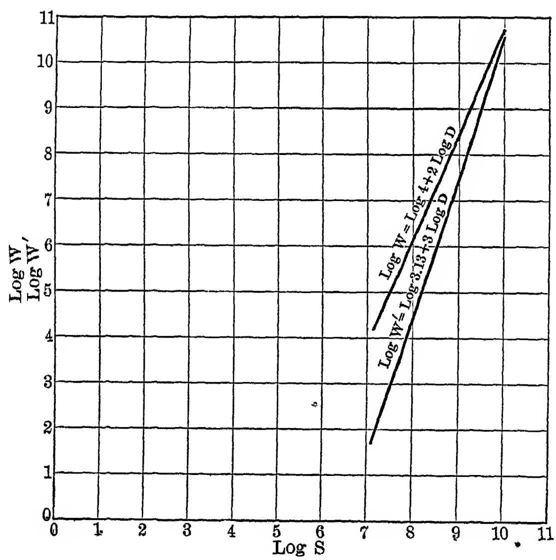

FIG. 9.

The graphs of these equations are shown in Fig. 8. They are closely parallel throughout a considerable range, showing the apparent agreement mentioned. The values near the origin of co-ordinates, where the agreement of the curves is least, are difficult to show in direct plotting. Fig. 9 represents the same equations plotted logarithmically. Here the divergence in the small sizes is very marked. That this is not wholly a mathematical divergence is apparent from the following quotation from Richards's *Text Book of Ore Dressing*, p. 170:

"Von Reytt has shown by a very exhaustive series of tests that the ratio of work done to increase the surface is fairly constant with coarser sizes, but that with fine sizes the increase of surface is much more rapid than the increase of work required to produce it."

In other words, the formula $W = KD^2$ gives high results in the fine sizes, as indicated by the upper curve, Fig. 9. If we look again at the tables given by Del Mar we see that in his second case, where the two methods agreed closely, there was but a small difference in the amount of very fine material in the two analyses given, while in his Case I there is a large difference and one of the percentages is very high. This aids the apparent agreement between the two methods of calculation in Case II and brings out the true divergence in Case I.

Summary

The work done in producing a given deformation of any body, within the elastic limit of the substance, varies as the volume of the body deformed.

For a highly elastic substance this principle may be extended beyond the elastic limit by the assumption that the force-deformation curve beyond the elastic limit is closely represented by a continuation of the straight line which represents the behavior of the body within the elastic limit.

For rock, which is almost perfectly elastic, this assumption is correct within the limits of experimental error.

The work of crushing rock is proportional to the volumes of the particles crushed, and to the volumes of the resulting particles.

Attempts to prove the work of crushing proportional to the reduction in diameter err in one of the following ways:

(1) By neglecting the distance quantity in the work formula.

(2) By assuming that particles in a crushing machine are acted upon in such a way as to produce simple shearing stresses.

(3) By assuming that the force exerted is a constant.

(4) By confusing "force" and "work."

The difference in the results obtained according to the two assumptions is small throughout a considerable range of sizes.

The difference is marked in the fine sizes, where the greatest amount of power is wasted.

In his original paper on this subject Stadler used 1 in. as the diameter of his unit grade and a volume reduction ratio of one-half for determining the other grades. He emphasized the fact that the method of calculation is independent of the screens used, the important matter to determine being the average diameter of grain in any grade. Then, by the formula $N = -10 \log S$, where N is the E. U. number for the grade and S is the average diameter, N may be determined. Unless, however, the screen apertures in the testing sieves used vary according to the ratio cube root of two, the values of N from Stadler's formulæ will not be whole numbers. This would be a trivial objection, since the slide rule is a part of the equip-

ment of all mills sufficiently up to date for screen analysis, if it were not for the fact that within the last year there has appeared in this country a set of testing sieves whose apertures vary according to the ratio square root of two, and which start from the U. S. standard 200-mesh sieve, 0.0029 in. clear aperture. This makes the coarsest screen of the series 1.050 in. clear aperture. Hence for this series of sieves the E. U. numbers of the different grades based on 1 in. as a unit will be all improper fractions, while with 1.050 in. taken as a unit the E. U. numbers are all whole numbers, and calculation with them is greatly simplified.

This difference in reduction ratio and unit aperture changes some of the formulæ originally stated by Stadler, and for the convenience of those who like to know the "why" of what they are doing and have not the time always to sit down and figure it out, the following proof, in general form, of the modified formulæ is appended. If we let

P = the number of pieces produced from the unit at any size,
S = sides of cubes (= mesh apertures),
V = volumes of cubes (or weights),
F = area of fracture with reference to unit,
R = ratio of increase in volume of the particles from one grade to the next,
N = Ordinal or Energy Number (E. U.) of grades,
U = Length of edge of unit cube,

the following relations are easily developed:

$$P = U^3/S^3 \quad (1)$$
$$P = U^3/V \quad (2)$$
$$S = \sqrt[3]{V}. \quad (3)$$
$$F = 3U^3/S \quad (4)$$

for F for any small cube broken from the unit equals $3S^2$ equals $3(U/n)^2$. And $P = n^3$. $S = U/n$. Hence F total $= 3PS^2 = 3n^3U^2/n^2 = 3nU^2 = 3U^3/S$.

$$S = 3U^3/F \quad \text{(from 4)} \quad (5)$$
$$P = U^3/S^3 \quad \text{(from 1)}$$
$$S^3 = 27U^9/F^3 \quad \text{(from 5)}$$

Then

$$P = F^3/27U^6 \quad (6)$$
$$V = U^3/P \quad \text{(from 2)} \quad (7)$$
$$S = \sqrt[3]{V} \quad \text{(from 3)}$$
$$= \sqrt[3]{U^3/P} \quad \text{(from 7)}$$
$$= U/\sqrt[3]{P} \quad (8)$$
$$V = S^3 \quad (9)$$
$$V = U^3/P \quad \text{(from 7)}$$
$$P = F^3/27U^6 \quad \text{(from 6)}$$

Therefore $V = 27U^9/F^3$ . . . . (10)

$F = 3U^3/S$ (from 4)

$= 3U^3/\sqrt[3]{V}$ (from 3) . . . . . . (11)

$F = 3U^3/(\sqrt[3]{U^3/P})$ (from 7 and 11)

$= 3\sqrt[3]{PU^2}$ . . . . (12)

$1/R = r =$ Volume reduction ratio.

For one reduction $V_1 = rV_0$
For the second reduction, $V_2 = rV_1 = r^2V_0$
For N reductions, $V_N = r^NV_0$
But $V_0/V_N = P$

Therefore $P = 1/r^N = R^N$. . . . . (13)

$S = U/\sqrt[3]{P}$ (from 8)

$= U/\sqrt[3]{R^N}$ (from 13) . . . . . (14)

$V = U^3/P$ (from 7)

$= U^3/R^N$ (from 13) . . . . . (15)

$F = 3\sqrt[3]{PU^2}$ (from 12)

$= 3\sqrt[3]{R^NU^2}$ (from 13) . . . . . (16)

$P = R^N$ (from 13)

Taking logarithms of both sides:

$\text{Log } P = N \log R$

$N = (\text{Log } P)/\text{Log } R$ . . . . (17)

$P = U^3/S^3$ (from 1)

Taking logarithms of both sides:

$\text{Log } P = \text{Log}(U^3/S^3)$

$= 3(\text{Log } U - \text{Log } S)$

Therefore $N = 3(\text{Log } U - \text{Log } S)/\text{Log } R$ . . . . (18)

$P = U^3/V$ (from 2)

Taking logarithms of both sides:

$\text{Log } P = \text{Log } U^3 - \text{Log } V$

Therefore $N = (3 \text{ Log } U - \text{Log } V)/\text{Log } R$ . . . . (19)

$P = F^3/27U^6$ (from 6)

Taking logarithms of both sides:

$\text{Log } P = \text{Log}(F^3/27U^6)$

$= \text{Log } F^3 - \text{Log } U^6 - \text{Log } 3^3$

$= 3(\text{Log } F - 2 \text{ Log } U - \text{Log } 3)$

Therefore $N = 3(\text{Log } F - 2 \text{ Log } U - \text{Log } 3)/\text{Log } R$ . . . (20)

Table of Formulæ for Determining Stadler's Constants

	P	S	V	F	N
P.....	....	U^3/S^3	U^3/V	$F^3/27U^6$	R^N
S.....	$U/\sqrt[3]{P}$	....	$\sqrt[3]{V}$	$3U^3/F$	$U/\sqrt[3]{R^N}$
V.....	U^3/P	S^3	....	$27U^9/F^3$	U^3/R^N
F.....	$3(\sqrt[3]{P})(U^2)$	$3U^3/S$	$3U^3/\sqrt[3]{V}$	....	$3\sqrt[3]{R^N}U^2$
N.....	$\frac{\text{Log P}}{\text{Log R}}$	$\frac{3(\text{Log U}-\text{Log S})}{\text{Log R}}$	$\frac{3\text{ Log U}-\text{Log V}}{\text{Log R}}$	$\frac{3(\text{Log F}-2\text{ Log U}-\text{Log }3)}{\text{Log R}}$	

$$N = \frac{3\text{ Log U}-\text{LogV}}{\text{Log R}} \quad \text{(from 19)}$$

Therefore

N = a function of V

But Work = Force $\times$ Distance

and Force varies as F

or Force = KF (where K is the average unit force to produce fracture).

Distance is a constant function of the diameter for any grade and is equal to a constant, C (determined by the modulus of elasticity of the material), times the diameter, or

Distance = CS

Therefore Work, to rupture one particle at any grade, = KFCS.

But there are P particles of any given grade in the unit.

Therefore W, to crush the unit volume (or weight) at any grade, = PKFCS.

But $$P = \frac{U^3}{V} \quad \text{(from 2)}$$

$$F = \frac{3U^3}{S} \quad \text{(from 4)}$$

Therefore $$W = \frac{U^3 \times S \times 3U^3 \times KC}{VS} = \frac{3KCU^6}{V}$$

That is, W = a function of V

But N = a function of V

Then W = a function of N.

Obviously, for sizes larger than U the value of N will be negative. In such a case the mechanical value of the pulp is the algebraic sum of the mechanical values of the individual grades.

The following table gives the values of N, P, V, S, and F for the Tyler standard screen scale sieves:

Constants for Tyler Standard Screen Scale Sieves

Apertures S		Volumes V (= S^3)		Area of fracture F (= $3U^3/S$)		No of pieces P (= U^3/V)	Ordinal or energy number. N(=Log P/LogR)
Inches	Millimeters	Cubic inches	Cubic millimeters	Square inches	Square millimeters	From unit	
1.050	26.67	1.1576	18,970	3.3075	2,133.8	1	0
0.742	18.85	0.40851	6,697.7	4.6804	3,019.1	2.8338	1
0.525	13.33	0.14470	2,368.6	6.6150	4,269.2	8.000	2
0.371	9.423	0.051063	836.7	9.3610	6,039.3	22.671	3
0.263	6.680	0.018192	298.09	13.205	8,519.2	63.635	4
0.185	4.699	0.0063316	103.76	18.772	12,111	182.83	5
0.131	3.327	0.0022481	36.826	26.511	17,105	514.94	6
0.093	2.362	0.00080434	13.178	37.343	24,093	1,439.2	7
0.065	1.651	0.00027462	4.5004	53.429	34,469	4,215.4	8
0.046	1.168	0.000097338	1.5934	75.497	48,723	11,893	9
0.0328	0.833	0.000035287	0.57803	105.88	68,317	32,806	10
0.0232	0.589	0.000012487	0.20434	149.71	96,618	92,704	11
0.0164	0.417	0.0000044108	0.072513	211.76	136,470	262,450	12
0.0116	0.295	0.0000015609	0.025672	299.39	192,910	741,630	13
0.0082	0.208	0 00000055176	0.0089988	423.53	273,600	2,099,600	14
0.0058	0.147	0.00000019511	0.0031766	598.77	387,140	5,933,100	15
0.0041	0.104	0.000000068919	0.0011238	847.06	547,200	16,797,000	16
0.0029	0.074	0.000000024389	0.00040522	1,197.5	769,040	47,464,000	17
0.0014a	0.037	0.000000003045	0.00004989	2,396.0	1,545,500	380,320,000	19

a Assumed

Discussion

A. O. Gates, LaFayette, Ind. (communication to the Secretary*).—I happen to be one of those who believe that Rittinger probably meant what he said when he wrote what Stadler has quoted, "the increase of the surfaces exposed is directly proportional to the force required for reducing" "*and therefore also to the work absorbed in effecting the separations.*" (The italics are now mine instead of Rittinger's or Stadler's.)

Our difficulty lies in not understanding just what occurs at the so-called "elastic limit." Up to this point the energy applied to the body is absorbed by it uniformly in proportion to volume. At the so-called elastic limit the first break occurs some place within the body, releasing the energy locally absorbed at the point and allowing a further deformation without a proportional amount of energy being absorbed. The cause of

* Received Mar. 3, 1914.

the first break within the body is that the ultimate strength of a single crystal, or of the bonding material between crystals, was exceeded. A series of these "local" breaks occur in sequence throughout the body until at some point several of these breaks lying close together so weaken it that the remaining crystals and bonding material are unable to resist further and the section fails, a fracture being the result. And except as energy has been absorbed in making these breaks and any heating of the material has caused radiation losses, the individual crystals of the rock are allowed upon release of the pressure to return to their original form (in conformity to Kick's law, if I understand it aright), and in so returning to this original form they return the energy they contained.

How is this energy returned? Either in pushing (or pulling) back the crushing faces, or, in accordance with a more universal law of nature, attacking the weaker part of the organization and completing the breaks upon the parts that have increased load put upon them by breaks alongside them.

I can conceive of a condition in a body in which a few individual crystals or groups of crystals are so interlaced that when the body is deformed by external pressure, and that pressure is released, these few crystals are so held that they are unable to return to their original shape. And Kick's law would apply to these, but the effect of the energy absorbed by these few crystals would have no appreciable effect upon the total of energy absorbed when actual crushing takes place.

I consider that the above reasoning applies to bodies in tension, shearing, or compression; it can be shown, I believe, that these three phenomena reduce to the same thing, the breaking of crystal or molecular bonds. I am quoting no authorities in support of my arguments, as it seems we have to be our own authority at times.

Mr. Taggart's paper is a disappointment to me in that he gives no experimental data in support of his argument. His use of Eads's experiment is not convincing; he has made an assumption that is unwarranted —namely, that all the deformation remains in the rock after fracture.

Von Reytt's experiments, which Mr. Taggart cites, were made with working crushing machines, in which there are big friction losses, in bearings mostly, the actual efficiency of which I consider to be less than 25 per cent., disregarding the energy spent upon the unmeasured fines, -0.1 mm. By efficiency I mean the ratio of energy absorbed by the rock to energy applied to the machine.

In his criticism of my arguments in The Crushing-Surface Diagram,[5] he might have analyzed by Stadler's method the two crushing-surface diagrams given as Figs. 4 and 5 in my paper. (The two cuts were transposed in making up the forms, and certain box areas were not marked

[5] *Engineering and Mining Journal*, vol. xcv, No. 21, p. 1040 (May 24, 1913).

thereon, although referred to on the cut.) A statement in my original copy that was edited out suggested such analysis by the members of the Stadler school. Provided my work was honest and reasonably accurate, a comparison of "E. U.'s" per foot-pound applied would be illuminating.

Answering Mr. Taggart, I do not presume to say that crushing takes place in commercial machines between offset faces as shown in the theoretical diagram I used to show the application of the law of Rittinger. I might have amplified it further by showing how the cracks actually occur in the breaking rock and how the broken pieces assume their original volume *in accordance with Kick's law.* But my paper was written with the purpose of explaining a new tool for mill operators, and I was hardly prepared to take at that time the full burden of the defense of Mr. Rittinger. I did what I could, and as I look over that argument now, it looks pretty good to me.

But why "argify"? The place to prove whether either law applies to crushing operations is in the laboratory, and there upon machines which will enable us to determine the energy absorbed by the rock, not in commercial crushing machines.

Some data of this kind I have at hand. I may say that it is all favorable to the law of Rittinger, and that it will be submitted to the Institute shortly.

Hallet R. Robbins, Pullman, Wash. (communication to the Secretary*).—It is with some trepidation that I venture to comment upon Mr. Taggart's excellent paper, which has done a great deal to clarify a subject heretofore somewhat obscure. The arguments brought forward in support of Kick's law are logical and convincing.

Mr. Taggart seems to have gone astray on those of his formulæ which involve F, the "area of fracture with reference to unit," or else he has not made his definition sufficiently clear. To my mind, F means the total area of all the planes of fracture which are assumed to pass through the unit cube, when this is broken into a number of smaller cubes of equal size. Using the notation of the original paper, the number of these planes of fracture is represented by the expression $3\left(\frac{U}{S} - 1\right)$. The area of each plane of fracture is U^2. The total area of fracture is then equal to $3U^2(\frac{U}{S} - 1)$ which may be written $\frac{3U^2(U - S)}{S}$. The results given by this formula may be checked by inspection and a slide rule for those cases where the unit cube is reduced in linear size one-half, one-quarter, etc. For example, to break into 64 cubes of one-quarter the linear size of the unit, it is readily seen there must be nine planes of fracture, each one $(0.896)^2$ or 0.8028 sq. in. in area; $9 \times 0.8028 = 7.225$, checking the figure in my table of constants.

*Received Mar. 31, 1914.

Based upon the preceding formula for F, I offer the accompanying revised table of formulæ for determining Stadler's constants.

Revised Table of Formulæ for Determining Stadler's Constants

	P	S	V	F	N
P		$\frac{U^3}{S^3}$	$\frac{U^3}{V}$	$\frac{(F+3U^2)^3}{27U^6}$	R^N
S	$\frac{U}{P^{\frac{1}{3}}}$		$V^{\frac{1}{3}}$	$\frac{3U^3}{F+3U^2}$	$\frac{U}{R^{\frac{N}{3}}}$
V	$\frac{U^3}{P}$	S^3		$\frac{27U^9}{(F+3U^2)^3}$	$\frac{U^3}{R^N}$
F	$3U^2(P_{\frac{1}{3}}-1)$	$\frac{3U^2(U-S)}{S}$	$\frac{3U^2(U-V^{\frac{1}{3}})}{V^{\frac{1}{3}}}$		$3U^2(R^{\frac{N}{3}}-1)$
N	$\frac{\log P}{\log R}$	$\frac{3(\log U-\log S)}{\log R}$	$\frac{3\log U-\log V}{\log R}$	$\frac{3[\log(F+3U^2)-2\log U-\log^3]}{\log R}$	

I have also calculated a table of constants for the sieves of the Tyler standard screen scale, based, not upon the aperture of the coarsest screen as a unit, but upon the average size of the product through the coarsest sieve on the next finer. The reason for this is that any product in a screen analysis consists of particles ranging in size between the apertures of the limiting screens. For all practical purposes it is proper to take as the average size of this product the mean of the apertures of the limiting screens. This is equivalent to assuming that the curve of crushing is a straight line between the points represented by two consecutive screens. A table calculated on the basis of the average sizes of the successive screened products should be more generally useful than one based on the apertures. For the sake of uniformity, I have followed Mr. Taggart's example in calculating the table to five significant figures, although three are all that is warranted, inasmuch as the screen apertures are accurate only to three significant figures, and in some instances even the third figure is inaccurate. The Energy Numbers in my table will not all be integers, if carried beyond three significant figures, for this reason.

For the Tyler standard screen scale sieves, $R = 2^{\frac{3}{2}} = 2.8284$, log $R = 0.4515450$, and $\log(\log R) = 9.6547010$; $r = \frac{1}{2^{\frac{3}{2}}} = 0.35355$, $\log r = 9.5484500$.

W. J. Sharwood, Lead, S. D. (communication to the Secretary*):—The author of this paper has done good service in attempting to clear

*Received April 20, 1914.

Constants for Tyler Standard Screen Scale Sieves

Apertures		Average Diameter of Product		Volumes $V = S^3$		Area of Fracture $F = \frac{3U^2(U - S)}{S}$		Number of Pieces from Unit $P = \frac{U^3}{V}$	Energy Number $N = \frac{\log P}{\log R}$
Inches	Millimeters	Inches	Millimeters	Cubic Inches	Cubic Millimeters	Square Inches	Square Millimeters		
1.050	26.67	0.896	22.76	0.71932	11,790.0	0.0	0.0	1.0	0
0.742	18.85	0.634	16.09	0.25484	4,165.5	0.99529	642.1	2.8826	1
0.525	13.33	0.448	11.377	0.089915	1,472.6	2.4085	1,553.8	8.0000	2
0.371	9.423	0.317	8.052	0.031855	522.05	4 399	2,838.0	22.581	3
0.263	6.680	0.224	5.690	0.011239	184.22	7.2253	4,661.4	64.00	4
0.185	4.699	0.158	4.013	0.0039443	64.626	11.280	7,277.2	182.37	5
0.131	3.327	0.112	2.845	0.0014049	23.028	16.859	10,877.	512.0	6
0.093	2.362	0.079	2.014	0.00049304	8.1692	24.908	16,069.	1,459.9	7
0.065	1.666	0.056	1.422	0.00017562	2.8754	36.126	23,307.	4,096.	8
0.046	1.178	0.0394	1.000	0.000061163	1.0000	52 362	33,781.	11,761.	9
0.0328	0.833	0.0280	0.711	0.000021952	0.35943	74.662	48,167.	32,768.	10
0.0232	0.589	0.0198	0.503	0.0000077624	0.12726	106.58	68,759.	92,668.	11
0.0164	0.417	0.0140	0.356	0.000002744	0.045118	151.73	97,889.	262,140.	12
0.0116	0.295	0.0099	0.252	0.00000097030	0.016003	215.57	139,070.	741,340.	13
0.0082	0.208	0.0070	0.178	0.000000343	0.0056398	305.87	197,330.	2,097,200.	14
0.0058	0.147	0.0050	0.126	0.000000125	0.0020004	429.19	276,880.	5,754,600.	15
0.0041	0.104	0.0035	0.089	0.000000042875	0 00070497	614.15	396,220.	16,777,000.	16
0.0029	0.074	0.0022	0.056	0.000000010648	0.00017562	978 49	631,260.	67,555,000.	17.34
0.0014*	0.037								

* Assumed.

up, for the average mill man, some of the difficulties involved in an understanding of the rival "laws" proposed for comparing the work of crushing. It is regrettable that more exact experimental data are not available, and the hope may be expressed that such data may soon be forthcoming.

Hydrometallurgists must regret to see Rittinger's law disproved, for surface exposed is, in general, a measure of the accessibility of solutions to ore; and this rule also ceases to approximate the truth only when the finest sizes are reached. If the premises are sound the author has evidently proved the case for Stadler's Energy Units.

The fact that F is not absolutely equal to $3U^3/S$ (as assumed on p. 168), but to $3U^3/S - 3U^2$, does not apparently invalidate the proof in any way.

There appears, however, to be a flaw in the supplementary reasoning on p. 170, for if

$$W = \frac{3\,K\,C\,U^6}{V} \text{ (7th line from foot)}$$

and

$$P = \frac{U^3}{V} \text{ (from (2), p. 168)}$$

we would have

$$W = 3\,K\,C\,U^3 \times P$$

where K, C, and U have all been assumed as having constant values.

Hence

$$W = \text{constant} \times P$$

That is to say, the work done, in crushing a given weight of ore from any one stage to the next, would, from this reasoning, be proportional to the *number of particles* at the first of these two stages. If this were actually the case, the law deduced would give, with the finer sizes, extremely large work values, even larger than Rittinger's increase of surface principle.

Apparently errors have been introduced in lines 13 to 16 from foot (p. 170), by assuming that the distance through which the force acts is C S; that is, that it is a constant product of the final dimension, rather than of the dimension before the breakage takes place. Again, in the next line we have: K F C S = work to rupture *one particle*, instead of *all particles*, although F has been previously defined as the fracture surface of the *total number of particles* derived from the original unit.

Crushing from one stage to another, several grades finer, may be effected in a number of ways. For instance, consider an 8-in. cube which is to be reduced to cubes of 1-in. edge. (1) It is conceivable that this might be done at one step, say by pressure applied at two opposite corners, breaking it, like Oliver Wendell Holmes's one-hoss shay, "all at once and all o'er," into 512 1-in. cubes (Fig. 10). Or (2) by a similar application of force it might break at the first stage into eight 4-in. cubes, each of which might again be similarly broken, *per saltum*, into 2-in., and these again

into 1-in. cubes. (3) A process of repeated bisection might be applied, the cube being first cleft into two 4-in. slabs, as in Fig. 11. These again may be bisected, either by a cut across a square face, as in Fig. 12A, or across a narrow face, as in Fig. 12B, each forming two "bricks" 4 by 4 by

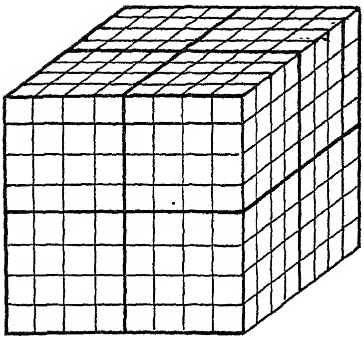

FIG. 10.

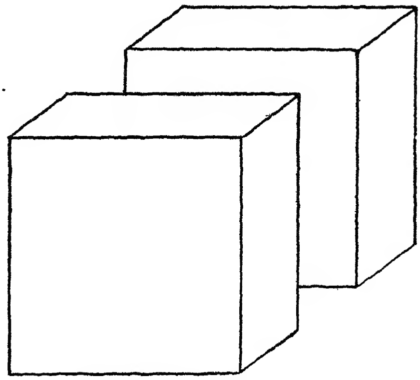

FIG. 11.

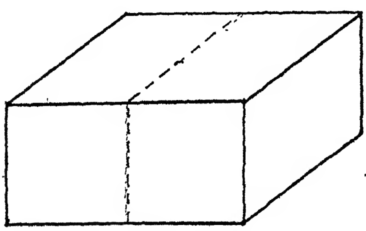

FIG. 12A.

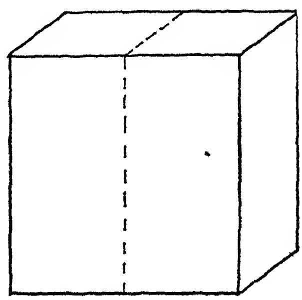

FIG. 12B.

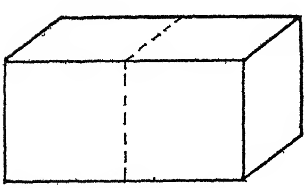

FIG. 13.

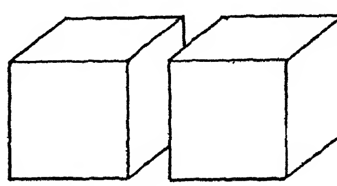

FIG. 14.

8 in., which are broken crosswise into 4-in. cubes. The cycle is repeated to give 2-in., and again for 1-in. cubes.

From reasoning on the lines followed by Mr. Taggart, it would seem that the first method requires the greatest, and the repeated bisection the smallest, expenditure of energy. This indicates that, from the standpoint of work, fine crushing is best effected in several stages.

One source of difficulty in following the reasoning is due, I think, to the choice of the particular ratio of diameters adopted for the successive stages. In this connection the following quotations may be cited from Mr. Stadler's reply to the discussion on his paper, as it originally appeared in the *Bulletin of the Institution of Mining and Metallurgy:*

"Just as coordinates, in analytical geometry, are a mere matter of convenience, so the determination of the sizes and steps in grading is simply a question of convention. Once, however, we have adopted a particular standard of measurement, we must stick to it. . . . I adopted the cube for the sake of mathematical simplicity. The sphere would have been equally suitable from a mathematical standpoint, but the reduction of a sphere to smaller spheres is not easily pictured in the mind, while the reduction of a cube to smaller cubes is easily imagined."

"By reducing the cube of the unit successively to *one-half of its volume*, and assuming these fractions to be again of cubical shape, each size of this series of theoretical cubes obtained represents a grade of a reduction scale of the ratio 2."

The successive diameters adopted by Mr. Stadler have, therefore, the ratio $\frac{1}{\sqrt[3]{2}}$.

When breakage of a cube is assumed to take place in a number of stages, at each of which the ratio of successive average diameters is the same; and if, as in the series considered by Mr. Taggart and by Mr. Stadler, this ratio is an irrational number such as $\frac{1}{\sqrt{2}}$ or $\frac{1}{\sqrt[3]{2}}$, it is a physical impossibility to carry out the comminution in practice.

If, for example, we assume the ratio of diameters to be $\frac{1}{\sqrt{2}}$ or 0.707, and we attempt to carry out one stage of crushing on a single unit cube, we find that we get only one resulting cube of the theoretical dimension, and the same for each consecutive stage; the remainder of the mass is necessarily broken up into pieces of indefinite size. The same is true of the ratio $\frac{1}{\sqrt[3]{2}}$.

A clear mental picture of the process, as suggested by Mr. Stadler, is undoubtedly desirable, but many people seem to find it difficult to conjure up a mental picture of one cube of rock being subdivided exactly into two cubes. It is, however, easy to understand the subdivision when the successive *linear* dimensions have a ratio corresponding to some simple fraction, preferably $\frac{1}{2}$, thus giving stages of crushing which can actually be realized, as for instance by the breaking of a single unit cube into eight cubes—either at one motion or by three successive bisections, as illustrated in Figs. 10 to 14.

On account of this fact that most people, whose mathematical faculties are only moderately developed, find it easier to follow the reasoning where the reductions in size are physically possible, it would seem de-

sirable to make the Energy Units conform to some integral ratio of diameters, preferably 2 : 1 rather than $\sqrt{2}:1$, and to make the intermediate values fractional.

This system has the advantage of simplicity, as it is easily remembered that each halving of the average diameter means an addition of one unit to the ordinal number. Thus in the case of Mr. Taggart's table (p. 171) the only change involved would be the division of all the numbers in the last column by two, each screen grade in the Tyler series corresponding to an ordinal number of $\frac{1}{2}$. If Hoover's $\sqrt[3]{2}$ series of screens were adopted, each successive screen would mean an addition of $\frac{1}{3}$ to the ordinal number. In a $\sqrt[4]{2}$ series the addition would be $\frac{1}{4}$, and so on.

The Burning of Coal Beds in Place

BY ALEXANDER BOWIE, BOWIE, COLO.

(New York Meeting, February, 1914)

In many places throughout the Western mountain plateau regions of the United States coal beds in place have been burned over very extensive areas, the fire evidently originating on the nakedly exposed outcrop of the coal bed and gradually burning its way into the bed for considerable distances under very heavy cover. The surface evidences of the burned-out coal beds are seen in the calcined and discolored rocks overlying the places of the outcrops. The greater the mass of the burned coal the higher the results of its combustion can be seen in the overlying strata. I have noted many instances of this condition in the States of South Dakota, Wyoming, Colorado, New Mexico, and Arizona. In the lignite fields of Dakota and Wyoming I noted stretches of level country many square miles in extent where the surface rocks were roasted and vitrified by the burning of a great bed of lignite lying nearly level and with a light cover; this is probably the most favorable natural condition for the burning out of a coal bed. The less the depth of the rock covering overlying the coal bed, the better the chance for a continuous supply of air to the fire; but when the coal bed dips heavily into the ground, or even if level, if it passes under a hill or mountain which gives the bed a heavy covering of strata, the fire has more chances of being extinguished from natural causes than in the first condition described.

The distance which a crop fire may extend into a coal field is very much influenced by the dip, the thickness of the coal bed, and the nature of the rock covering immediately overlying it.

In reasoning on this subject, it would seem logical to assume in the case of a coal-bed cropping at the base of a hill and dipping into it, with an extensive drainage surface above the crop line, that a crop fire would be promptly extinguished by the caving in of the overlying strata and the precipitation of the rainfall from the drainage surface above the outcrop through the breaks formed in the caving strata. This consideration would be more or less effective according to the climate of the location and the nature of the overlying strata. In a humid climate where the rainfall was heavy the water from the natural precipitation alone would probably extinguish a crop fire before it could work its way very far under cover, but in an arid climate this preventive does not seem to be effective.

I find that even under the conditions I have suggested as being most unfavorable for the continuity of crop fires there are places where fires have persisted for long periods of time until the fire has eaten its way under a heavy cover for distances from a few hundred feet to a half mile or more from the outcrop before it was finally extinguished.

In my mining experience two such cases have come under my observation, one in the development of the Caledonian mine, near Gallup, N. M., at an elevation of 6,500 ft. above sea level, and the other in the development of the mines of the Juanita Coal & Coke Co., in Delta county, Colo. In both cases the coal bed dipped away from the outcrop and in both cases the land rose for a considerable distance above the coal crop, forming a large drainage area, the run-off from which had to cross the line of outcrop.

In the Caledonian coal bed the coal was a high-class lignite about 6 ft. thick at the outcrop, with a stratum of hard sandstone about 25 ft. thick for a roof. As the mine was driven into the field a seam of soft clay shale, which gradually increased to a thickness of from 3½ to 4 ft., came in between the top of the coal bed and the sandstone roof. The coal was found burned out at one point to a distance of nearly 500 ft. from the outcrop. In developing the mine we cut through into places where the sandstone roof stood up in its natural position unbroken and the upper half of the coal bed was burned off. All that was left of it was a few inches of fine white ashes covering the lower half of the coal bed, which was not consumed, but metamorphosed so that its cohesive property was destroyed and it was nothing but fine slack that would not ignite when placed on an ordinary fire. In this case the influence of the fire did not extend far beyond the place of the burning, as a few yards beyond the burned-out area we got coal of a quality good enough to ship. There was no evidence that water had played any part in extinguishing the fire, as the fine ashes overlying the under part of the coal bed were undisturbed; it had evidently expired for want of air by the packing of the earth between the fire and the outcrop. It occurred to me at the time that if the 4 ft. of soft clay shale had formed the roof of the coal bed at the outcrop the fire would have been smothered by the shale before it could have burned its way many feet from the outcrop.

I had an opportunity for further observation at the mine of the Juanita Coal & Coke Co., which is located on the north side of the North Fork branch of the Gunnison river, at an elevation of about 6,600 ft. above sea level. The mine is named the King mine and we refer to the bed in which it is opened as the King coal bed. At the point where the mine is located the stream flows nearly west and the high banks run approximately parallel to it and rise high above it on both sides. On the north side the surface rises abruptly to an elevation of from 1,200 to 1,500 ft. above the level of the stream and continues to rise for many

miles northward. The King mine is opened on the north side about 700 ft. above the level of the stream and 80 ft. above a great cliff-making sandstone ranging from 100 to 150 ft. thick, which forms the base of the coal formation and is commonly referred to as the basal sandstone. The mine enters on the outcrop of the coal bed, which comes to the surface at that point, although the coal is burned out along the outcrop on both sides of the opening. There is only a sparse covering of soil in patches along this hillside, the rocks for the most part being nakedly exposed, and one can trace the horizon of the coal bed in which the mine is opened for long distances and find nothing but calcined rocks. The dip of the coal bed is northeast and the main line of the development of the mine is northward; the rate of dip on the line of the main entries is about 5 per cent.

The coal mined next the outcrop was very soft and continued to be of inferior quality for about 700 ft. or more in from the outcrop.

The coal adjacent to the burned-out area seemed to have its cohesive quality entirely destroyed. It was soft and very easily mined, but could not be utilized even for steam fuel, as the volatile constituents of the coal seemed to have been expelled by the heat. Our customers complained that it lay dead on a fire and would not burn. We had a zone of several hundred feet of this kind of coal, which gradually became less fragile until we had coal that could be utilized for steam fuel; but passing it over a screen would yield a very small quantity of lump coal, a large percentage of nut and a still larger percentage of slack, while great clouds of fine dust would rise over the screen during the screening operation. This condition gradually improved until about 800 ft. from the outcrop a fair quality of coal was mined.

The plan of mining was to turn off entries in pairs to the right and left from the main line of development. The inferior quality of the coal found next the outcrop had the effect of deferring the opening of these side entries, but ultimately we turned off three to the left, the last one about 1,800 ft. from the outcrop. All of the three entries broke through on an area where the coal had been burned out entirely, at distances ranging from 350 to 500 ft. west from the main entry, and in each case our mine was flooded by the water confined in the caved material. No other entries have been driven to the left beyond the third left entry, so that the conditions beyond that entry remain undetermined.

In the first two cases when the water broke through from the burned-out area into our mine workings, it came in such volume that we were unable to approach the opening from which it issued. After the water had partly drained off we made an effort to reach and examine the opening from which it came and were at first prevented from approaching it by the efflux of black damp, which promptly extinguished a miner's lamp. This condition gradually improved as the flow of the water decreased;

before it was fully discharged we were able to approach the opening, and found that the pressure of the water had burst a hole larger than an ordinary barrel through a wall of coal several feet thick. Looking through this hole we saw quite an open space along a vertical wall of charred coal. The coal bed varies from 8 to 10 ft. or more in thickness. The roof of the bed on the west side of the mine is a massive sandstone of variable thickness which breaks in great rectangular blocks. At the point where we broke through the roof strata had been sufficiently strong to resist breaking close along the face of the burned coal, but had broken several feet back from the face, and between the great blocks of sandstone which formed the base of the caved material there were many vacant spaces. It was in these interstitial spaces that the water that flooded our mine had lodged. There was no means of deciding whether the fire that had consumed the coal bed had been extinguished from want of air and an influx of water had occurred later, or if it had been quenched by the water. There were no fine ashes visible as in the case noted in the Caledonian mine. They seemed to have been all washed out by the water. The greater part of the first flood was disposed of by siphon; the last two had to be pumped. We tried to use the mine water in a boiler to raise steam for the pump, but failed because it foamed so badly. We tried all the known remedies for foaming, but still it foamed. We sent samples of the water to three of the principal firms that advertise the treatment of impure water to fit it for boiler use. They all gave it up as being unfit for use. I give herewith an analysis of the water.

"*Mineral Analysis*

	Grains per gallon
Silica	0.666
Oxides of iron and aluminum	1.576
Carbonate of lime	Trace
Sulphate of lime	83.952
Carbonate of magnesia	118.910
Sulphate of magnesia	303.989
Sodium and potassium sulphates	810.395
Sodium and potassium chlorates	14.960
Loss, etc	0.108
Total soluble solids	1,334.556
Suspended matter	3.971
Total soluble incrusting solids	509.093
Total soluble non-incrusting solids	825.463
	Pounds
Soluble incrusting solids per 1,000 U. S. gal	72.73
Soluble non-incrusting solids per 1,000 U. S. gal	117.92

"Contains a little over 1,334½ grains of solid matter in solution and a little less than 4 grains in suspension, per U. S. gallon of 231 cubic inches.

"This water is absolutely unfit to be considered as a boiler feed supply, as it will not only cause the formation of a decidedly large amount of incrustation which will be exceedingly hard, impervious, persistent, tenacious and compact, but will also cause, under practically every condition, trouble in the way of foaming, priming, corrosion, pitting, oozing out at and causing leaky joints, destruction of gaskets, etc."

The water doubtless contains everything that was soluble in the coal ashes, besides the salts it accumulated in its passage through the strata overlying the coal bed. This all happened on the west side of the mine. It should also be noted that at a place about 2,000 ft. west of the opening along the burned outcrop there is a point that was considered a good place to open a mine when the development of the property was first considered. A pair of drifts were opened there on the plane of the coal bed and driven in 600 ft. or more, following a streak of ashes all the way, but as no coal was found the two drifts were abandoned. The present opening was then located. No unusual heat was noted when approaching the burned-out areas on either the east or the west side of the mine and the natural inference is that the fires which consumed this great body of coal are extinct.

On the east side of the mine the first drain entry was turned off about 2,000 ft. from the pit mouth and was driven eastward in the coal bed about 1,600 ft. to a gulch, where an opening was made to the surface. The outcrop between the pit mouth and this gulch is all burned out, and when rooms were turned off this entry and driven out toward the outcrop, in a short distance they all ran into inferior coal of the same nature as that found in opening the mine. In consequence of this fact none of them were driven out far enough to hole into the burned area.

About 80 ft. vertically below the burned outcrop I have been describing is the place of the lowest coal bed in the formation, on the top of the basal sandstone. About 2 miles east of the King mine this bed is only a foot thick. Following the outcrop westward it increases in thickness to 4 ft. at the King mine and continues to increase until it shows about 6 ft. of coal a mile or more west of the King mine. This coal bed is nakedly exposed in many places along the outcrop. In view of the condition of the outcrop of the King coal bed I thought it remarkable that the lower coal bed showed no evidence of being burned on the outcrop for 2 miles or more on each side of the mine. The natural conditions to which they had been exposed for many years were identical and I could not imagine why one bed should have been burned by many fires of independent origin while the other had escaped ignition entirely.

I give herewith an analysis of both coal beds by Prof. William P. Headden.[1]

[1] *Proceedings of the Colorado Scientific Society*, vol. viii, pp. 293 and 294 (1907).

Juanita, four and one-half foot seam. Specific gravity, 1.351.

Proximate Analysis *Air-Dried Coal*		Ultimate Analysis *Pure Coal*	
Moisture at 100°	2.175	Carbon	79.918
Volatile	34.447	Hydrogen	5.033
Fixed carbon	54.173	Nitrogen	1.813
Ash	9.205	Sulfur	0.968
		Oxygen	12.268
	100.000		100.000

Calorific value determined, air-dried coal, 7116 calories, 12809 B.T.U.; pure coal, 8030 calories, 14454 B.T.U.

Juanita, fourteen foot seam. Specific gravity, 1.318.

Proximate Analysis *Air-Dried Coal*		Ultimate Analysis *Pure Coal*	
Moisture at 100°	1.000	Carbon	82.920
Volatile	27.432	Hydrogen	4.479
Fixed carbon	66.863	Nitrogen	1.746
Ash	4.705	Sulfur	0.643
		Oxygen	10.212
	100.000		100.000

Calorific value determined, air-dried coal, 7674 calories, 13813 B.T.U.; pure coal, 8138 calories, 14648 B.T.U.

Coals with a high moisture and low carbon content are supposed to be the most liable to spontaneous combustion, but in this case it is the coal bed having a relatively higher moisture and lower carbon content that has escaped ignition at the outcrop.

Tracing the horizon of the King (burned-out) coal bed eastward along the north bank of the river, in 5 miles we reach the Somerset mine. The coal bed in which this mine is opened is identical with the King seam and has increased in this distance to double the thickness found in the King mine, but the lower part of the seam is so impure that only the upper half of it is mined. The Somerset mine is also opened to the north and developed by entries driven to the right and left. The entries driven to the left, with one exception, were driven a certain distance west and then had to be stopped on account of excessive heat. I am reliably informed that temperatures as high as 180° F. have been registered by a thermometer placed in a hole drilled in the coal in this hot area. In 1904, I visited the mine and saw miners wearing gloves to load coal because it was too hot to be handled with naked hands. There was a good current of air, but the temperature was 112° F. The last entry driven to the west, about 4,000 ft. in from the outcrop, seems to have succeeded in getting past the hot area, as temperatures as high as 140° F., registered by a ther-

mometer placed in a hole drilled in the coal, have gradually decreased to a normal temperature. The outcrop of the coal bed west of the mine is all burned. It is well above the level of the stream and an opening to the surface would be convenient and desirable, but every attempt to drive out to the surface from the interior of the mine has been frustrated by the heat.

On the mountain side above the area where the source of the heat seems to be located, about $\frac{3}{4}$ mile west of the mine and at an elevation of about 600 or 700 ft. above the coal bed, hot gases showing a temperature of 150° F. issue from rents in the strata. This phenomena was noted by the early settlers in the valley long before the mines were opened and the place was not inappropriately christened "Fire mountain" and is still known by that name. An analysis of the gas issuing from one of the crevices on the mountain was made by the U. S. Bureau of Mines (George A. Burrell, chemist) from a sample taken during 1911. The analysis shows: CO_2, 15.51; O_2, 3.29; CO, 0.00; CH_4, 0.23; N, 80.97; total, 100.00 per cent.

The cause of the abnormal heat in the Somerset mine and of the hot gases escaping from Fire mountain is generally believed to be the smoldering residue of an ancient crop fire, although one prominent member of the mining fraternity prefers laccoliths and thermal waters as a means of accounting for the phenomena.

With regard to the manner in which crop fires may originate, the suggestion that they may have been started by forest fires or camp fires built on a nakedly exposed outcrop seems to find more favor than any other mode of causation. While these causes have been in as active operation in the Eastern States as they have been in the Western, the difference in conditions may reasonably be held sufficient to account for the difference in results. I have traced the place or position of coal outcrops for long distances in Pennsylvania, West Virginia, in the western part of Virginia, and in other Eastern States without seeing any actual exposures of coal. Ordinarily the coal crop is covered with humid soil several feet deep, which forms a good protection to the coal bed from any surface fire. Naked exposures of coal beds are rare and I cannot recall seeing a burned outcrop in any of my examinations of coal fields in Eastern States.

In many places in the Western States the outcrops of coal are only partly concealed by a slight covering of soil and naked exposures along outcrops are frequent, and may show for several hundred feet at a stretch. The climate is arid and the vegetation scanty, consisting mostly of greasewood, sage brush, pinon and cedar trees, that will live with little moisture at any time but after a protracted dry spell become as dry as tinder and furnish good fuel for a fire. During nearly every summer for the past seven years I have seen trees on the north bank of the North

Fork of the Gunnison struck by lightning and burn fiercely until they were consumed. Some of these trees attain considerable magnitude, and it seems reasonable to believe that if one or more large burning pinon or cedar trees fell across the nakedly exposed outcrop of a coal bed sufficient heat might be generated to set it on fire.

That very slight differences in climate may create conditions more or less favorable to the ignition of the outcrop of coal beds is well shown in this neighborhood by comparing the north and south banks of the North Fork. The coal formation is exposed on both sides of the stream, and both banks rise abruptly 1,500 ft. more or less above the drainage level. The north bank receives the full force of the sun's rays nearly all day. There being little rainfall, the soil becomes so parched with the heat that it will support very little vegetation. The soil, what little there is, is loose and incoherent, and when rain does come it carries the loose soil with it to lower levels. When snow falls, it rarely lies on the ground more than one day; it melts and goes off rapidly; and the erosion from snow water is just as effective as that from rain, so that the rocks on the north side do not commonly accumulate any considerable covering of soil. On the other hand, the south bank is partly shaded from the sun, and does not receive the full force of its rays as the north side does. Snow lies nearly all winter on the south bank, melts gradually, and sinks into the soil wherever there is any soil to absorb it; vegetation has therefore a better chance to survive on the south bank. The vegetation holds the soil together so that the erosive action of the rainfall is not so great as on the north bank, and the rocks are more frequently clothed with a kindly covering of soil, which has the natural effect of making burned outcrops less frequent and not so extensive as they are on the north bank.

It is also worthy of note that on both banks where the outcrop crosses a gulch or drainage line of any considerable magnitude the coal is not burned out. This statement is not invariably true. The protection of the coal beds in the gulches is doubtless due to their being partly shaded from the sun, and the consequent accumulation of soil and denser vegetation, which restrains erosion, just as on the north bank.

If a coal bed lies under heavy cover and is burned out along the outcrop there is no possible means of determining by surface examination how far the fire has extended into the coal field, or of defining the limit of the burned-out area. The only surface evidence of the burning will be found in the calcined and charred rocks along the geological horizon of the outcrop of the bed, and in the fractured and displaced overlying rocks where the roof covering is shallow.

The rule stated is applicable to the burned-out areas adjacent to the Somerset and King mines, and under ordinary conditions will apply to coal beds of equal or lesser thickness elsewhere. The burning of a mam-

moth coal bed would be likely to form an exception to this rule, for obvious reasons.

The belief that crop fires do not extend far from the surface is responsible for the purchase as coal land of hundreds of acres of land that contains no coal, taxes being paid on it as coal land for a long term of years until mining development proves the coal is burned out.

During the time the King mine has been in operation we have never received any complaints or heard any report of the coal having taken fire spontaneously when stored in large heaps, and at the mine on two occasions we had to unload and store slack in heaps 10 to 15 ft. deep, which lay undisturbed for several months without showing any signs of spontaneous combustion or even heating perceptibly; nor have I ever heard of any spontaneous fires in coal from the Somerset mine. But we have had three fires in the King mine from spontaneous combustion, which in each case originated in the débris from falls in the east side of the mine. In this part of the mine the deterioration of the coal bed already described extends so far in from the crop line and the roof of the bed is also found to be so much affected as to raise the suspicion that a coal bed not far above the one we are now working has been burned. This idea was strengthened by observing the structure of the roof, as soon as we had some falls in that part of the mine. I give a section herewith of the roof material in which the spontaneous fires were generated.

Massive sandstone.
White clay, 2 ft.
Coal smut, 1 to 2 ft.
Blue clay, 2 ft.
Coal, 1 ft.
Bone coal, 6 in.
Coal, 1 ft. 6 in.
Bone coal, 4 to 6 in.
Parting.
King coal bed, 10 ft. 6 in.

The strata above the parting form the roof of the workings in the King coal bed. The coal found above the parting is all rather impure and contains much pyrites; even the clay when heated gives off strong sulphur fumes. The coal smut looks like coal that had been reduced to a fine powder and compacted just enough to hold together, but is easily crumbled to dust between the thumb and forefinger. It is the débris from this section of 8 or 10 ft. above the coal bed where the smut is found that generates spontaneous fires. The roof is difficult to maintain; when it breaks it comes down in small fragments and packs close.

Elsewhere in the mine where the smut is not found we have drawn a block of pillars. The roof was good, and when we had a break it came down in great blocks. On several occasions we noted that the temperature in these falls was several degrees hotter than in our return airways,

but the block of pillars was cleaned out without noting any temperature high enough to excite fear of spontaneous fire. The temperature on top of the falls runs up to 88° F.; the ordinary temperature of our return airway was about 64°. Whenever we had a break in drawing pillars or a fall of rock of any considerable magnitude we commonly found on climbing up over the fall that as soon as we got a few feet above the level of the roof our lights were promptly extinguished. At the time referred to both oil lamps and calcium carbide lamps were used in our mine. We found the acetylene gas flame would continue to burn in air that would extinguish the flame of an oil lamp. Whenever a miner comes in contact with gas that puts out his light he promptly labels it black damp. So it was in this case, but I noticed that this gas did not descend to the floor, even in the most isolated places where there was no air current. Consequently I concluded that the extinction of the flame in our lamps was due to some other gas. W. D. Scofield, of the U. S. Bureau of Mines, took samples of the air from the top of two of the falls and also from behind one of the stoppings where we had a fire walled off. These samples were analyzed by George A. Burrell and gave the following results:

Atmosphere from Walled-off Area.—CO_2, 3.62; O_2, 16.28; CO, 0.00; CH_4, 0.05; N, 80.05; total, 100.00 per cent.

Air on Top of Fall.—CO_2, 1.22; O_2, 16.60; CO, 0.00; CH_4, 0.25; N, 81.93; total, 100.00 per cent.

Air on Top of Fall.—CO_2, 1.30; O_2, 16.68; CO, 0.00; CH_4, 0.25; N, 81.77; total, 100.00 per cent.

It is remarkable that there is no CO in any of these samples, not even in the walled-off inclosure where the fire had been. Neither of the samples from the top of the falls, in which a light would not burn, showed enough CO_2 to extinguish a flame. The failure to support combustion in both cases seems to have been due to a reduction in the oxygen and a relative increase in the nitrogen content of the air. The decrease in the oxygen was probably due to slow combustion that did not generate enough heat to reach the temperature of ignition for the carbonaceous matter contained in the débris but doubtless caused the increase of temperature noted.

The burning of coal beds in place and the conditions which generate the fires that ignite them, as well as the spontaneous generation of fires in mines, is an interesting subject to the coal-mining fraternity and I have recorded my observations in the hope that it may prompt some other members of the craft to do likewise, as we have very little literature on the subject.

Discussion

G. H. Williams,* Bowie, Colo. (communication to the Secretary†).—I have seen this burning, not only in Colorado, but in New Mexico and

* Non-member.

† Received June 4, 1914.

Utah. The physical evidences shown on the surface are the same in all cases I have observed: the rock overlying the burned coal bed is discolored and fractured, and hot gases and water vapors escape through the fractures where the coal bed is still burning. In Utah I have seen the sandstone and shale overlying the burned-out coal bed actually slagged by the heat and showing the appearance of lava rather than any resemblance to sedimentary rock.

Some miles from Raton, N. M., there is a coal bed that has been burned at the outcrop which is still undergoing the process of combustion.

The burning is still going on at Somerset, but I question whether it is in the seam that we are working at present. It seems to me more probable that it is in one of the upper seams, one of which is 6 or 7 ft. thick.

In prosecuting the work at the Somerset mine we ran into burned coal in the heated area and drove a certain distance into the burned and crushed material. The temperature observed was no greater than when driving in the coal, neither were there any noxious gases encountered in noticeable quantity; this was probably due to the tendency of the air to escape upward through the crevices in the overlying rock. The greatest heat observed in thė Somerset mine was in the Second Rise entry, a short entry driven toward the rise or outcrop on the west of the slope. We never reached any point where combustion was still going on, but this entry was abandoned on account of the heat, although it was still in solid coal, at a point 1,750 ft. in from the place of the burned outcrop. A wall was built across the entry some distance back from the face and a pipe fitted with a valve was left in the wall, through which a thermometer could be inserted. I give herewith a record of four thermometer readings taken through the pipe.

	Degrees F.		Degrees F.
February, 1906	199	June, 1907	210
June, 1907	204	December, 1907	220

Later quite a large area embracing the Second Rise entry was permanently walled off, although no fire was actually found in this or any other part of the heated area.

We attempted to penetrate or get through the heated area west of the slope with several levels, all of which attempts were unsuccessful and had to be abandoned on account of the heat. Finally we got through it with one which is over 6,000 ft. in length, in which we finally reached practically normal temperature on the other side. The following temperatures were recorded in driving this entry:

Temperatures Recorded in Driving Sixth West Entry, Somerset

	Length, Feet	Temperature, Degrees
Station 396—from Main Slope	2,250	...
	2,365	115
	2,396	136
	2,460	138
	2,510	141
	2,628	144
	2,804	138
	2,875	138
	3,120	124
	3,375	109
	3,638	98
	3,803	95
	4,488	92
	4,608	80
Total length of entry to date	6,418	

The highest temperature was recorded in April, 1910.

In approaching the heated area in the coal we kept drill holes ahead of the face of the entry and found temperatures as high as 220°. Steam under more or less pressure escaped from the holes with a whistling sound. We found no evidence of explosive gases being given off in the heated area. In fact, no gas was found where the greatest heat prevailed.

I imagine the combustion of the coal under these conditions, at least after a heavy cover is reached, is flameless. Of course, we never reached any point where combustion was actually going on. At one place we extracted a large area of pillars in the heated zone, and a very marked cooling took place after the rooms were driven and while the work of drawing the pillars was going on. After caving took place, however, the temperature again rose, due probably to lack of ventilation and the heat in the rock both above and below the coal bed. This area was all walled off eventually for fear that spontaneous combustion might take place, the supposition being that the old workings would fill up with black damp, which would prevent combustion. Some pipes with valves in them were left through the walls, but nothing in the nature of black damp was ever discovered, and I presume that the gas discovered may have been similar to that described in the paper. We never saw any evidence of fire in the worked-out and walled-off area in the heated zone, although the heat of the strata in places was over 200°. In the vicinity of Somerset, in places at least, I imagine the burning of the outcrop has about reached its limit, as the cover is so great that the cracks formed by the caving of the strata overlying the coal cannot reach the surface. In fact, I have noticed places where the gas does not escape any longer through a vertical crack, but comes out through a horizontal crevice at

the base of a very heavy sandstone ledge several hundred feet above the coal bed, which seems to indicate that no more crevices can be formed in the future through which oxygen can be furnished for combustion.

Our entry penetrating the heated area has gone below and beyond this point. I mean by below further down the dip of the strata and of course a long distance below vertically.[2] The coal here is practically dry, and, while I imagine that the burning is in a seam above the coal bed we are working, I know of no reason why this upper seam, which is presumably on fire, can contain any more moisture, either chemical or mechanical, than the one we are working. There certainly would not be enough water to furnish oxygen by disintegration (if such a thing is possible) to carry on combustion, and apparently there is very little water seeping in from the surface, so I take it that the supply comes from the outside where it will have very little chance to reach the point of burning hereafter, as the breaking and loosening of the strata cannot continue to reach the surface any longer. In fact, no vertical crevices reach the surface now; presumably they reach the bottom of the heavy sandstone ledge and from there go out horizontally some unknown distance to the surface.

One peculiarity in the burning of the coal seams which I have noticed in Utah is that there are in places what might be termed islands of unburned coal. In most, if not in all, cases this coal has lost considerable of its volatile matter and has acquired more or less of the luster of anthracite, but the bituminous coal structure has not been destroyed. Those areas which I have described as islands of unburned coal are bounded on one side by the outcrop and on the other three sides by a burned-out area so as to really isolate the island of coal from the body of the coal field.

I know of one case in Utah where a mine opening was made on quite an extensive piece of apparently unaffected coal, but after the entries had been driven in 200 or 300 ft. burned coal was encountered, which continued for a distance of 600 or 700 ft. I have never observed a place where the effect of the burning has extended to as great an extent into the unburned coal as Mr. Bowie mentions. In any case where we have run up against the burned coal in our mines in Utah there was no evidence of it until we were 25 or 30 ft. from it. At our Sunnyside mine, where we make coke extensively, we have to watch its coking quality carefully when approaching the burned coal, as the coking qualities are affected before there is any change in the coal that can be discovered by ocular

[2] We have not less than 800 ft. of cover on this entry. We are probably working under a heavier cover than any other coal mine in the United States. A point at the surface, the elevation of which is definitely determined, is 2,500 ft. above the level of the coal bed at a point about 400 or 500 ft. beyond the present face of one of the levels in the mine. A *Bulletin* of the Department of Mines, published a couple of years ago, gives 2,200 ft. as the deepest coal being worked in the United States.

examination; still we find coal possessing its full coking quality within 50 ft. of where the seam or part of it has been actually burned out. A fault or fracture line, however, may carry the effect of the burning coal a considerable distance farther; we have found places where the gases from combustion have condensed and penetrated all the fracture planes of the coal and left the most beautiful analine dye stains imaginable, arranged in streaks shading off irregularly one into the other.

ALEXANDER BOWIE (communication to the Secretary*).—The belief of Mr. Williams that the fire at the Somerset mine is in a coal bed above the one now being mined is possibly correct, but that phase of the question must remain a matter of opinion until we have more evidence than we now have on the subject.

His statement that "where we ran up against the burned coal in our mines in Utah there was no evidence of it until we were 25 or 30 ft. from it" coincides with the experience we had on the west side of the Juanita Co.'s King mine. My statement describing the peculiar condition of the coal next the outcrop should be modified by stating that it applied to the ground developed by the main entry and the region east of it, and not to the west side of the mine. The seam of coal smut on the east side of the mine which we found 5½ ft. above the seam we are now working, and which we believe to be a partly burned coal bed that was responsible for the peculiar condition of the coal below it, does not exist on the west side of the mine.

Even if we assume that we are correct in the supposition that the heat generated by the coal bed of which the smut is the residue was the cause of the deterioration of the coal bed we are working, it does not necessarily follow that we should have the same result at Somerset from the burning of an upper bed, as it is quite possible that a coal bed might be on fire above the one being mined, and near enough to give it a great deal of heat, but too far away to affect the physical characteristics of the coal.

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* Received June 4,1914.

To What Extent is Chalcocite a Primary, and to what Extent a Secondary, Mineral in Ore Deposits

A discussion at the New York Meeting, February, 1914

L. C. Graton, Cambridge, Mass.—The subject of chalcocite occurrence and its geological significance has, of course, a very important commercial bearing, as shown by the recent remark of a hard-headed mining man: "This secondary enrichment business is one thing you geologists have put up which we can hang on to, and come out right."

Most enrichments of copper ores depend upon the formation of chalcocite from leaner sulphides. Recently it has been shown that not only does there exist this secondary or derived chalcocite, but that in certain ores the mineral is present as an initial or original constituent, which therefore we may call primary. The desirability of distinguishing between these two kinds of chalcocite is evident and has recently been emphasized. That constitutes the first problem in this connection. I believe many who are working upon secondary enrichment of mineral deposits are giving much attention to that particular question.

It is now possible to distinguish primary from secondary chalcocite in many cases. In such cases, what do we know of the conditions under which this secondary or derived chalcocite was formed? This is the second main question in connection with the subject. It is now plain, at least in many instances, that the formation of this derived chalcocite represents a phase of oxidation if we have in mind the primary ore as the thing acted upon. The next important question—and it is most important—is: does such oxidation go on above the zone where the rocks are saturated with water—that is, above the water level—or below, or indiscriminately above and below?

Many of you have, or have had, opportunities to study at first hand, day after day, occurrences that enable valuable conclusions to be drawn upon these and other important questions concerning the formation and significance of chalcocite. It is greatly to be hoped that your testimony will be made available and undoubtedly it will go far toward clearing up some of these doubtful points.

John D. Irving, New Haven, Conn.—A short time before this meeting was called, H. V. Winchell, who was unable to be present, requested me to exhibit and describe these two samples of pyrite. (Exhibiting specimens.) They consist of fragments of pyrite inclosed in two small bottles. The first bottle shows fragments of pyrite which were immersed in water carrying copper sulphate but without SO_2 for a period of two years. They remained comparatively clear and bright. No chalcocite has been deposited on them. The second bottle shows fragments of

pyrite which were immersed in a solution in every way similar except that it was saturated with SO_2. Immersion was for a period of one year. On removing the pyrite it was found to be coated with gray metallic chalcocite. The coating covers all parts of the pyrite grains, so that unless the grains are broken or scratched they appear to be solid chalcocite.

Members of the Institute may recall that in 1903 Mr. Winchell contributed an article[1] in which he described certain experiments in the precipitation of chalcocite by pyrite from mine waters. The specimens which have been exhibited are those of the pyrite which was used in the original experiments described by Mr. Winchell. The portion of his paper which deals with these experiments is found on pages 272 to 275 of the article above mentioned. In order that the meaning of the specimens may be clear to the members the following paragraphs are quoted from Mr. Winchell's paper:

"*Artificial Formation of Chalcocite*"

"After considering the geological history and physical structure of these ore deposits, the writer came to the conclusion some three years ago that the copper glance was formed by a chemical reaction between copper sulphate in solution in descending waters and the iron pyrites and other primary sulphide minerals lying below. In order to ascertain the truth or falsity of this theory, laboratory experiments were undertaken by the writer and carried on by Messrs. S. J. Gormly and C. F. Tolman in the laboratories of the Anaconda Copper Mining Company.

"The first experiments were conducted with a relatively small amount of cupriferous pyrite and a dilute solution of copper sulphate. The results, as reported, show the formation first of SO_2 and then of H_2SO_4; the solution of both copper and iron and the precipitation of the iron as ferric hydrate, and the formation of copper sulphide.

"Analyses of the mine waters showed no ferrous salt in the strong copper water, but disclosed the presence of quantities of cuprous salts, in acid solution.

"The experiments repeatedly showed that SO_2 is formed by the action of pyrite and chalcopyrite upon $CuSO_4$, and that the SO_2 reduces some of the copper ions of the $CuSO_4$ to the cuprous form. According to theoretical chemistry, a relatively insoluble compound may be precipitated by very small amounts of a salt containing one of the ions of the insoluble compound, if a large amount of the salt containing the other ion is present. To test this, a solution of copper sulphate was treated with the sulphides of arsenic, lead, copper, iron, zinc, and with pyrite; and in each case copper sulphide was precipitated, proving that these sulphides may precipitate copper sulphides from a solution of a copper salt. It is probable also that the more insoluble the precipitating sulphide, the more concentrated must be the solution of copper sulphate.

"To produce a solution containing cuprous ions, the above mentioned sulphides were treated with a solution of copper sulphate ($CuSO_4$) and SO_2, and precipitates were formed in each instance. An analysis of the precipitate formed by copper sulphide showed a precipitation of 12 per cent. of the weight of the original CuS as Cu_2S, indicating the formation of chalcocite under these conditions.

[1] Synthesis of Chalcocite and Its Genesis at Butte, Montana. *Bulletin of the Geological Society of America*, vol. xiv, pp. 269 to 276 (1902); also *Enginering and Mining Journal*, vol. lxxxiv, No. 23, pp. 1067 to 1070 (Dec. 7, 1907).

"It was not ascertained whether the iron salts will reduce enough copper to form Cu_2S in presence of pyrite or other sulphides, or whether the SO_2 formed by solution of the pyrite and other sulphides is the active agent.

"Knowing full well that it might be urged that the formation of a precipitate of a certain chemical composition is quite a different matter from the production of a mineral having the same composition, the experiment now about to be briefly described was undertaken and carried to completion with exceedingly gratifying and satisfactory results.

"In a slightly acid solution containing sulphurous anhydride (SO_2) was digested pyrite (FeS_2) at ordinary temperature and pressure for three months. The pyrite taken was ordinary 'jig concentrates,' about one-fourth of an inch in diameter, from the Parrot concentrator at Butte, and of the following composition:

SO_2	8.30
CaO	Trace
MnO	None
Fe	41.20
Cu	1.50
Zn	0 20
S	48.70
	99.90

"Dividing these results by the molecular weights, the molecular constitution is represented as follows:

Fe	0.736
Cu	0.024
Zn	0.003
S	1.522

"After standing for three months in an ordinarily well lighted room, inclosed in a sealed jar to exclude the atmosphere, the formerly yellow grains of pyrite were completely plated with a solid coating of a dark blue-black mineral, and so closely resemble grains of solid chalcocite that they can only be distinguished from the latter by breaking them open, while in another jar which stood alongside, similarly sealed and exposed to light and ordinary temperature, containing pyrite and copper sulphate solution (but no SO_2), the grains of pyrite were just as bright and yellow as before they were immersed. Indeed, there has been no visible alteration on the surface of grains which have now been thus immersed in copper sulphate without SO_2 for two years, while in an adjacent jar containing SO_2 there has been formed what appears to be, and undoubtedly is, a fine coating of chalcocite.

"From the first jar there were taken some of the larger grains for analyses, with results as follows:

SiO_2	9.60
CaO	.....
MnO	.....
Fe	40.10
Cu	3.60
Zn	.....
S	43.60
	99.60

CaO, MnO and Zn not determined

"The molecular constitution is now Fe, 0.716; Cu, 0.057, and S, 1 448. There are .016 equivalents of sulphur left over (after calculating the iron as FeS_2) to unite with the copper. The exact theoretical amount to form Cu_2S is .014, and the surplus sulphur may be combined with zinc, lime, or manganese. That the mineral coating thus formed on the jig-concentrates is clearly chalcocite can not be doubted from a mere inspection of the samples and comparison with ore from the mines."

So much has been said in discussions on secondary chalcocite concerning the prevalence of a black powder, or what is commonly known as "sooty chalcocite," that Mr. Winchell desires to call the attention of the members to the fact that the chalcocite secured in his experiments was not of the sooty variety, but rather of the usual gray variety with metallic luster. It forms, as may be seen in the sample which stood for a long time in water carrying an excess of SO_2, a thin, glistening, grayish coating on the outside of the pyrite and bears no resemblance to the usual "lamp black" variety.

While the "sooty" type is therefore to be considered as secondary, the gray massive variety may likewise originate in the same manner.

THOMAS T. READ, New York, N. Y.—In 1905 I did some experimental work along much the same lines as that which Mr. Winchell has done, because it was so obviously of great significance, and found that the presence of SO_2 was apparently exceedingly effective in bringing about this condition. The action was not at all marked in the absence of SO_2, but where the SO_2 was present it was very marked.

A difficulty in drawing conclusions from this fact, however, is that W. H. Emmons reports that he has been unable to detect the presence of SO_2 in mine waters. Geologists commonly regard SO_2 as a reducing agent, possibly because SO_2 is the agent in which we used to reduce gold chloride in the laboratory, in order to precipitate gold. But SO_2 is, obviously, exceedingly rich in oxygen, and toward FeS_2 might act as a fairly strong oxidizing agent. That induced me, at that time, in a paper presented to the Institute, to suggest that the action of copper sulphate on the sulphides is ascribable to ordinary oxidation and that secondary sulphides might be considered to be oxidation products, just as, for example, in the copper converter, from a sulphide which is quite low in copper you can, by oxidation, get one which is high in copper. The rich sulphides of copper may be and in some cases doubtless are due simply to the effects of oxidation on lean sulphides.

L. C. GRATON.—In connection with the synthetic production of chalcocite, it may be pointed out that results like those in which Messrs. Winchell and Reed produced coatings on the primary sulphides, are indeed positive, but that negative results, such as their failure to secure such reactions without the presence of SO_2, cannot be relied upon with entire safety as indicating that in nature some reducing agent like SO_2 is required for the operation of the secondary enrichment process. The

function of time in a process of this sort as carried on in nature must be given due consideration and it may very well be that a chemical reaction which exhibits no measurable progress during a period of a few weeks or months or years might advance to a very important degree in the course of a short time as measured in geologic units.

It is of interest to note that the chemists of the Geophysical Laboratory of the Carnegie Institution in Washington, who have been at work for something over a year on the general problem of the copper sulphides, have sought to steam up or intensify the processes of nature by agitation and by increased temperatures but without increasing the concentration of the solutions over those of the natural reagents. Under these circumstances it is possible to produce measurable results in probably much shorter time than nature would have required. The particular point of interest in this connection is that by treating pure pyrite with a dilute acidified solution of cupric sulphate, they have been able to secure coatings of a substance which both chemical and microscopic analysis shows to be actually chalcocite—and this without the intervention of any reducing agent, or at least any other reducing agent than the original sulphur-rich sulphide, itself—viz., pyrite.

Professor Kemp, I believe, was the first to suggest that the excess sulphur in the mineral attacked, such as pyrite, pyrrhotite, etc., might be responsible for the evident reduction of the copper sulphate to sulphide. If one grants that the copper to produce enrichment has come from overlying portions in the form of sulphate, its ultimate precipitation as sulphide can be brought about in no other way then by chemical reduction, if one has in mind the copper so precipitated; if, on the other hand, one thinks of the primary sulphides acted upon, the process is one of oxidation.

The axiomatic fact that no oxidation can take place without equal reduction appears to have been temporarily overlooked by some in the discussion of this subject. The secondary deposition of chalcocite, therefore, may be called the result of either oxidation or reduction, depending on the viewpoint. But since the ultimate reagents involved are the atmosphere and the original primary sulphides, and since we are accustomed to think of the changes experienced by the latter rather than by the former, it follows that the development of chalcocite as an intermediate step in the reaction may most naturally be regarded as due to oxidation.

Another topic has been mentioned upon which I should like to say a word, and that is the matter of sooty chalcocite. My experience to date leads to the belief that sooty chalcocite may as well be produced from primary chalcocite as from secondary chalcocite, provided it comes within the reach of the oxidizing, disintegrating influences near the surface. The original precipitation or beginnings of precipitation of secondary

chalcocite upon pyrite, as may be best studied in the case of a definite pyrite crystal undergoing conversion to chalcocite at its surface, produces a coating that always, so far as I have observed, is of dense, massive chalcocite—the steely chalcocite or glance of the miner; and so long as chalcocite continues to form, it is of this massive, steely variety. If, however, the conditions favoring the deposition of chalcocite cease and oxidation or solution of the chalcocite begins to ensue, then around the edges of the individual chalcocite grains decomposition or solution goes on, the individual grains are reduced in size, and the whole mass becomes lusterless and incoherent, just as a cake of ice becomes dull and crumbly when left in the sun. This dull, friable, decomposing, and disintegrating material is, in reality, the so-called "sooty" chalcocite.

In the paper on the New London mine, Maryland, now offered for publication in the Institute records by B. S. Butler and H. D. McCaskey, of the U. S. Geological Survey, it is interesting to note that they find primary chalcocite and bornite associated in a manner similar in all essential respects to that now known at various places in the Piedmont Plateau region. This reference perhaps affords an opportune occasion to modify certain conclusions regarding primary chalcocite stated by Mr. Murdoch and myself[2] at the meeting a year ago. In one instance was described what we regarded as primary chalcocite in the ores of Bisbee. There was but little of the mineral present in the material we studied, but at the time the evidence seemed satisfactory. Since then, in that identical material, we have found in the chalcocite exceedingly minute residues of bornite distributed in such fashion and showing such character as to leave practically no doubt that the chalcocite had been derived from bornite, that it was, therefore, secondary and not primary, and presumably had been produced in the ordinary course of enrichment. We also stated our belief that the chalcocite of the Bonanza mine, in Alaska, is primary; that is, the result of initial deposition. Very recently, in going over the same material upon which we reached that conclusion, we find there also exceedingly minute and possibly doubtfully identified bornite, but sufficient to raise the same doubt as to the character of the chalcocite, and this doubt is somewhat strengthened by the finding, in material taken from about the deepest workings of that mine, bornite in considerable abundance, altering to chalcocite and chalcocite-pyrite, with smaller amounts of some other minerals. So our minds are very much unsettled as to the nature of the Bonanza chalcocite, and we are a little inclined to fear that our earlier conclusion regarding it may be erroneous.

F. L. Ransome, Washington, D. C.—I wish to express my agreement with Professor Graton that much of the so-called sooty chalcocite is a disintegration product of the ordinary chalcocite with bright metallic luster; but some caution should be exercised in the interpretation of the

[2] Trans., xlv, 26 (1913).

term "sooty chalcocite" as found in literature. In a mass of fine-grained friable pyrite that has undergone partial change to chalcocite, each grain is coated with chalcocite and each little coating, examined microscopically, may be lustrous dense chalcocite. Yet the general appearance of the whole is that of a dull black, friable material. Much of the sooty chalcocite referred to in literature is material of this sort.

WALDEMAR LINDGREN, Boston, Mass.—I want to say that we are accumulating new observations so fast we are in danger of forgetting some of the old ones. The other day I came across something I suppose every mineralogist knows perfectly well, and that I think most mining geologists have forgotten—although they knew it at one time—and that is that beautiful crystalline chalcocite occurred at the Bristol mine, in Connecticut, formerly the greatest producer in the United States—that is also news to you. Specimens of these ores which are in the Massachusetts Institute of Technology, and I suppose they are in other places, show perfectly clearly, as far as my examination has gone, primary chalcocite in beautiful crystals, and primary beyond any reasonable question.

In the hunt for primary chalcocites that occurrence seems to be overlooked, and I thought I would call attention to it, in case it should happen that anybody knows anything about the occurrence, who has studied it. I think it is, except the crystals from Cornwall, of which I do not know much personally, the most beautiful and sharply crystallized chalcocite that has ever been found.

JAMES F. KEMP, New York, N. Y.—At the meeting of the Geological Society this winter, in Princeton, Professor Van Hise, of the Chase Scientific School, exhibited some crystals of bornite that only two or three of us had ever seen, and they also came from the Priestly mine, in Connecticut. I do not know whether we are justified in saying that there is an association of bornite and chalcocite, just at the moment, but this association seemed to hold good. Bornite is a rare thing to find in crystals, although common enough in mass form. Chalcocite, likewise, we seldom get in crystals, but the forms that were obtained from Priestly, Conn., were mentioned in the earlier mineralogy of this country, as to the forms of chalcocite. It would be interesting if Professor Ransome can develop some new matter from these old forgotten sources of copper.

The Origin of the "Garnet Zones" and Associated Ore Deposits

BY WALDEMAR LINDGREN, BOSTON, MASS.

(New York Meeting, February, 1914)

During the last 15 years much attention has been given to the "contact-metamorphic" ore deposits which mainly occur in limestone close to intrusive contacts. In general, these deposits are characterized by the association of magnetite and simple sulphides with the so-called "contact-metamorphic" silicates. These silicates comprise garnet, epidote, vesuvianite, tremolite, wollastonite, diopside, hedenbergite, ilvaite, and many other rarer forms. The contact-metamorphic zones contain also in places minerals with boron, fluorine, and chlorine, like axinite, tourmaline, danburite, fluorite, and scapolite. There is also more or less quartz and coarsely recrystallized calcite. The simple sulphides embrace pyrite, pyrrhotite, chalcopyrite, galena, zincblende, more rarely arsenopyrite. On the whole, sulphantimonides and sulpharsenides are rare. Deposits of magnetite or chalcopyrite or of both are most common.

The deposits have an irregular or rudely tabular form, following main contacts, dike contacts, or stratification planes; they rarely extend for more than 1,500 or 2,000 ft. from the contact; far more commonly they only reach a distance of a few hundred feet from that surface. The deposits are usually formed by replacement of limestone, or allied calcareous rock. Apparently they are found both in relatively pure and in impure carbonate rock.

The deposits are geological bodies of a chemical and mineralogical character differing greatly from the adjoining intrusive rock and from the unaltered limestone. They are rich in silica and iron, with more or less of lime, magnesia, alumina, sulphur, and rarer metals like copper. The so-called contact-metamorphic silicates which form the gangue usually are coextensive with the metallic minerals, though of course not necessarily with the merchantable ore. All opinions agree in holding the deposits of epigenetic origin, later than the inclosing limestone.

Regarding the origin of the metals and the genesis of the ores there are several opinions.

1. There are those who see in these deposits the result of concentration of material contained in the intrusive rocks by means of hot circulating

waters of atmospheric origin; the circulation established being upward on the periphery of the hot mass.

"The heated ground water would be quite competent to do all that is ascribed to magmatic waters, including the formation of lime-silicate zones."[1]

Among the minority who still cling to this view I find Professor Lawson. The latter, writing with his customary well-sharpened pen, describes the magmatic theory of these deposits as "one of the fashionable vagaries of our time, not entitled to serious respect as a scientifically established theory."[2] I am inclined to hope that Professor Lawson has already changed this view. If he has not I am sure he will before long, especially if he should undertake a somewhat careful study of a considerable number of the contact-metamorphic deposits in the Southwest and in Mexico.

In the first place, these deposits are "high temperature" deposits. The character of the gangue minerals shows that they were formed at considerable depth—some well within the zone of fracture, perhaps only 4,000 ft. below the surface—others deep down in the region where fracturing must be considered impossible. In both cases the essential characteristics are the same. According to our best information the lowest temperature at which garnets, diopside, etc., may form is about 400° or 500° C. In view of the well-grounded attacks lately made upon the theory of the deep circulation of atmospheric waters it devolves upon the supporters of the view set forth under (1) to explain the possibility of such a circulation upward along the contact at temperatures of from 300° to 1,000° C. The Daubrée experiment will really not suffice any more as an explanation.[3]

I shall try to make the real position of the leaching theory a little clearer: The metals, etc., were extracted from the intrusive rock—that is, from a hot body having a temperature of from 500° to 1,500°—and deposited in the adjacent, cooler sediments, say at temperatures from 300° to 1,000° C. Consequently the circulation of the atmospheric waters would really take place in a lateral direction and not simply *along* the contact as maintained by Lawson. The silicates present in the contact zone prohibit the assumption of concentration at lower temperatures.

No one who has observed many deposits of this kind can fail to be impressed with the fact that the ores are generally found at limestone points projecting into the intrusive mass, or in slabs of limestone swimming in the igneous rock. It is difficult to see why the circulating atmospheric waters should seek such places by preference. In many

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[1] Lawson, A. C.: *Mining and Scientific Press*, vol. civ, No. 5, p. 201 (Feb. 3, 1912).

[2] *Loc. cit.*

[3] Johnson, John, and Adams, L. H.: Observations on the Daubrée Experiment and Capillarity in Relation to Certain Geologic Speculations, *Journal of Geology*, vol. xxii, pp. 1 to 15 (1913).

deposits there is no evidence of fractures or paths which could have been followed by the water.

Inevitably, such a hydrothermal circulation as is suggested by Professor Lawson would result in a strong alteration of the intrusive. In many instances there is no such evidence of replacing solutions. Fresh granitic rock often borders the ore.

Mineralized later fractures may, however, cross these contact deposits and then the intrusive rock may be hydrothermally altered, but this does not prove that this is caused by atmospheric waters. It is clear, of course, that thermal metamorphism is not denied by Lawson; and he also admits a so-called "reactionary metamorphism wherein the changes are due to reaction between the encasing rocks and the materials emanating from the intruding mass."[4] Thus for instance he would class the hornfels of Clifton and that from the Kristiania region as the result of thermal metamorphism. But the overlying limestone when it contained andradite and magnetite and sulphides would be a product of circulating atmospheric waters. Truly an odd position to defend!

It has been asserted that these deposits are exceptional cases, because they do not occur along all contacts or along the same contact. The answer to this is that the economically valuable *deposits* are exceptional but the *mineralization* is not, as one often can ascertain by carefully following one of these contacts.

2. There is another school, of which C. K. Leith is perhaps the most prominent exponent. These men do not by any means deny the actuality of emanations from the magma, but hold that the silicate gangue minerals are mainly the result of a recrystallization of constituents originally contained in the limestone, like calcium, magnesium, iron, aluminum, and silica. This involves of course a great reduction of volume since the latter three constituents are usually subordinate in limestones, the removal of a great deal of material, and a compression obliterating structures and textures. The additions from the magma are laid mainly to a late stage during which the silicates containing mineralizers and the iron ores were introduced. "The metallic minerals may be either direct contributions from the magma, or hot water deposits resulting from the working over of the hot intrusives."[5] No statement is made as to the derivation of this water but atmospheric waters are probably meant.

Much effort has been expended in attempting to prove the first part of the proposition: namely, the development of the silicates by a reduction of volume of the limestone amounting to 40 to 80 per cent. The last paper with this end in view has been contributed by W. L. Uglow,[6] who endeavors to show by comparison of analyses of fresh and altered lime-

[4] *Loc. cit.*

[5] *Economic Geology*, vol. viii, No. 1, p. 26 (Jan., 1913).

[6] *Idem*, vol. viii, Nos. 1 and 3 (1913).

stones that the ratio of silica to alumina and ferric oxide is constant. The analytical material is evidently insufficient, especially as several of his analyses of "fresh" limestones already contain silicates. That no such constancy is shown has been clearly pointed out by C. A. Stewart.[7]

Few of the analyses have separate determinations of Fe and Al in the unaltered limestone. Were such determinations available I suspect that the non-constancy in the ratio Al:Fe would be still more apparent.[8]

Mr. Uglow also attempts a general *critique* of the literature and theory of contact-metamorphism deposits, but in this he is evidently handicapped by lack of field experience.

The main argument of the supposition of the "residuary crystallization" theory is that the impure limestones with much silica are the ones which yield the contact-metamorphic silicates. This is of course largely a question of facts. Evidence that cannot easily be refuted has been introduced to show that the contact-metamorphic silicates and the ores often form in very pure limestone. But it is conceded that they may also develop in impure limestone. According to the supporters of the residuary crystallization theory, a very large reduction of volume has been effected in either case, which of course would make the stratification a jumble near the contact. The expulsion of so much calcium and magnesium carbonate involves first a development of porosity and then a compression by the stresses from the intruding magmas. The reason why most silicate zones are composed of hard, compact rocks is therefore that the porous rock has been strongly compressed. (In some cases one is tempted to add that the rocks, upon this theory, must have been principally pores.) Later, upon cooling, contraction fissures appeared and received some emanations from the magma or material concentrated by hot water from the intrusive rock.

I must here refer to the Washington Camp in Arizona, described by Professor Crosby. According to his statement the silicates and ore in the Pride of the West mine have been formed from an impure limestone. I investigated this occurrence carefully in 1909 with F. C. Schrader, of the U. S. Geological Survey, and was reluctantly compelled to adopt a different view. It seemed to me that a stratum of particularly pure limestone had here been replaced, lying between beds of markedly impure and siliceous limestone which have suffered little alteration.

That part of the pure bed which is converted into ore and silicates presents the unusual feature that the altered material contains some rather large druses, which are coated by fine quartz crystals. In this case, then,

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[7] *Economic Geology*, vol. viii, No. 5, p. 501 (Aug., 1913).

[8] I find that the analysis given by Mr. Uglow for the "Modoc limestone" at Clifton has been obtained by taking the average of the two analyses from Modoc mountain, which of course is correct, and one analysis, materially different, from Shannon mountain, 3 miles distant. This is, to say the least, a curious proceeding.

the pressure of the magma was not great enough to compress a drusy material into a compact mass.

It should be added that many of these silicate rocks as exposed at the surface appear porous and drusy, but this is usually caused by the solution of interstitial and residuary calcite.

Thus far no conclusive field evidence has been introduced showing the compression demanded by the "residuary" theory. We owe probably the best and most careful examination of a metamorphic zone to Professor Barrell.[9] He concludes that in the outer metamorphic zone there must have been effected a considerable compression, for which he, however, found no convincing field evidence; while the inner zone, in which additions from the magma seemed clearly demonstrated, showed no evidence of reduction in volume. Theoretically, according to Barrell there should be a slight expansion in this zone.

It is obviously impossible that structures and textures could be retained on the residuary crystallization theory. That such structures are in fact often retained has often been shown and I have particularly called attention to the preservation of fossils in greatly garnetized rocks at Tres Hermanas, N. M.

F. C. Calkins and B. S. Butler have recently completed careful investigations of contact zones at Philipsburg, Mont., and San Francisco, Utah.[10] In both cases evidences of porosity or compression were sought for but not found.

It seems as if a careful microscopic study of limestones in all stages of recrystallization would convince any one that no such wholesale reduction of volume has taken place. Delicate needles and prisms of amphibole or pyroxene or skeletal forms of garnets appear which are not disturbed or crushed by the metamorphism in more advanced stages. A part of the limestone may be replaced by quartz, and both calcite and quartz are without disturbance traversed by a system of amphibole prisms.

The tendency of crystallization in skeleton forms leads to the so frequent development of residual calcite included in the silicates. I can find little to contradict the conclusion that the metasomatism takes place by equal volumes and that there is practically no change in volume in the altered rock compared to the original rock.

The advocates of the residual crystallization theory reluctantly admit that boron, fluorine, etc., may have been introduced. Are they sure that these were the only elements introduced? It seems to me absolutely impossible to draw a line between the ordinary silicates and those containing mineralizers. Both are commonly intergrown, showing practically contemporaneous origin. Take for instance the occurrence

[9] *Professional Paper* No. 57, *U. S. Geological Survey* (1907).

[10] *Professional Papers* Nos. 78 *and* 80, *U. S. Geological Survey* (1913).

of axinite, which so frequently has been overlooked, the brown massive mineral looking much like garnet.[11] Sulphur has equal right to be regarded as a mineralizer and from Day's and Shepherd's work at Kilauea[12] we know that even the surface lava gives off much more sulphur than fluorine and boron. Even if nothing more is admitted in the way of emanations it is clear that sulphides may result in the adjoining rocks. Has the old experiment been forgotten showing the development of magnetite in a limestone fragment immersed in molten basalt?

I do not intend to deny for an instant that the impurities in a limestone may be utilized in its subsequent recrystallization and I have noted the wollastonite developing at the contact of chert nodules and limestone as described by Crosby from Washington Camp, but I do insist that if it is admitted that a massive andradite garnet may form from a practically pure limestone no amount of diagrams can prove that the constituents of the garnet can be accounted for by residuary crystallization.

3. The view that accounts for the silicate minerals, and the minerals containing mineralizers, and the iron ores, and the sulphides by assuming that they are derived in large part from the emanations from the magma seems to me so plausible, so convincing and so fitting when the subject is regarded from a broad standpoint that I cannot help joining Kemp, Spurr, Goldschmidt and many others in advocating it. I believe thoroughly that iron, silica, various rare metals, the mineralizers, to a smaller degree also alumina and the alkalies, are thus contributed by the intrusive. The limestone and the intrusive emanations form a chemical system in which reactions of great intensity are proceeding. Sometimes there is also a vigorous interaction between the limestone and the intrusive, as shown by the occasional development of epidote and garnet in the latter.

The emanations consisting of gases, water, and volatile compounds in which the metals are probably carried as chlorides or fluorides, penetrate the limestone easily. In connection with this I wish to call your attention to some diagrams and mathematical calculations presented by Messrs. Leith and Uglow in which it is shown how excessively slow the diffusion of heat is from an intrusive contact. No doubt the calculations are correct, but their presentation is an excellent instance of the danger of applying mathematics to geology. The diffused heat is as a matter of fact a feature of minor importance. The penetration of the emanations into the solid rocks is the main cause of the contact metamorphism. These emanations penetrate the suitable strata of limestone as if the latter were a sponge and they also travel rapidly on fissures and joints. Convection thus far outdistances diffusion. Every geologist who has studied contact

[11] Schrader, F. C.: *Bulletin No.* 497, *U. S. Geological Survey* (1912).

[12] *Bulletin of the Geological Society of America*, vol. xxiv, No. 4, pp. 573 to 606 (Dec., 1913).

metamorphism is well aware that certain beds, not unlike those above and below, show extraordinary selective power of recrystallization and mineralization. It is well known that some limestones are easily penetrable by oil, so that they may be rendered strongly translucent by such impregnation. If this can be effected at lower temperatures what would be the effect of emanations under tremendous pressure and temperature?

The principal differences among those who believe in the magmatic theory relate to the order of introduction of the various minerals. Some, like J. E. Spurr, hold that the development of silicates preceded the metallization as a more or less distinct stage and make of the latter a hydrothermal phenomenon taking place after the consolidation of the intrusive magma. Others see a rather continuous process in the metallization, holding that it began at the moment of irruption.

It has always seemed to me most difficult in this case to separate metamorphism and metasomatism. I am inclined to minimize the purely thermal metamorphism, and this opinion is strengthened by the extremely slow rate of diffusion of heat. On the other hand, it is well known, for instance, through the work of F. C. Calkins,[13] that the emanations resulting in tourmaline and scapolite spread long distances from the contacts. It is therefore probable that the metamorphism which so often extends for many thousand feet from the contact is primarily induced by the transmission through the pores, fractures, and bedding planes of solutions emanating from the magma but mingled on their way with interstitial rock moisture. In fact, the slowness of the diffusion of heat positively compels such a view. The replacement will ordinarily proceed by equal volumes, but where the movement of the solutions was extremely rapid drusy texture might result. All this is on supposition that the locality is in the zone of fracture. If it is definitely in the zone of flowage, the temperatures could normally be much higher and the difficulty of escape of the carbon dioxide would naturally be much greater. Hence the development of silicates would proceed at a very much slower rate, so slow indeed that porosity would become improbable and any replacement would proceed on the basis of equal volumes; any material dissolved would immediately be replaced by new minerals.

In the diffusion of emanations from the magma certain constituents would penetrate much further than others. Carbon dioxide and other gases would certainly penetrate much further than silica, for instance.

There is unquestionably a certain sequence in the development of minerals in contact zones. Many observations seem to prove that emanation of sulphides and magnetite continues after the contact action, resulting in silicate rock, is completed, and finally hydrothermal action results.

[13] *Professional Paper No.* 78, *U. S. Geological Survey* (1913).

The strong advocates of this view, among whom J. E. Spurr is prominent, seem, however, to minimize unduly the earlier development of sulphides and magnetite. I have often had occasion to emphasize these early accessions which I think cannot be denied. The recent literature contains little to make a change of opinion necessary. B. S. Butler,[14] for instance, says of the Frisco district, Utah, that "in general the minerals of the contact zones appear to have formed at essentially the same time, though in some places metallic minerals have formed later than the silicates as well as contemporaneously with them." T. Kato,[15] describing the deposits at the Okufo mine, Japan, states that wollastonite is the oldest mineral and that it was formed by accessions of silica. He considers the earliest solutions to have been very siliceous. Next follows andradite with traces only of alumina; this is intergrown with vesuvianite. The sulphides were formed contemporaneously with the garnet or at the closing epoch of its deposition. Veinlets of chalcopyrite form the latest manifestation of metallization.

In conclusion, I would say that the most convincing argument in favor of the derivation of these deposits from emanations from the magma is not this or that single fact, but the great chain of circumstantial evidence which connects the contact-metamorphic deposits with the high-temperature veins on one hand (such as the cassiterite veins, for instance) and the pegmatitic veins and dikes and concentrations in molten magmas on the other hand. In some cases evidence of this kind, with grading to ordinary veins, indicating lower temperatures, is offered in the vicinity of a single intrusion. If to this is added the direct evidence of emanations from the surface lavas, for instance of sulphur and fluorine from the Hawaiian volcanoes, the whole forms a well-supported theory which should require respectful consideration even from those who would attribute a paramount rôle to the atmospheric waters.

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[14] *Professional Paper No. 80, U. S. Geological Survey*, p. 84 (1913).

[15] *Journal of the Geological Society of Tokio*, vol. xx, pp. 13 to 32 (1913).

Recrystallization of Limestone at Igneous Contacts

BY C. K. LEITH, MADISON, WIS.

(New York Meeting, February, 1914)

At the outset I would like to make it clear that I do not enter this discussion in a controversial spirit, but in an attempt to contribute something helpful to an understanding of a difficult problem. I have too high regard for the sterling quality of the work of the men who have studied this subject in detail to offer anything in the way of essential contradiction to their statements of fact. Difference of opinion arises from differing valuation of the possible alternative hypothesis which these facts suggest.

Some degree of recrystallization in limestone contact zones has been recognized by many investigators. Earlier investigators, for the most part, assigned an important, if not the most important, rôle to recrystallization in development of these zones. With the growing recognition of introduction of ores and gangue materials into the contact zone from igneous rocks through the medium of primary magmatic solutions, there has been a tendency to ascribe to this process most, if not all, of the chemical and mineralogical characteristics of the contact zone. This has involved a correspondingly diminished emphasis on recrystallization of substances already there as a factor in the process, and in some cases even the complete elimination of this hypothesis. From detailed study of a few contacts, casual observation of others, and a general familiarity with the literature, some of us have been led in recent years to raise the question whether the pendulum has not swung too far away from recrystallization toward direct introduction from igneous sources, and to argue for more recognition of the part played by recrystallization.[1] The inevitable sequence has been that those of us who have taken this view have been charged, at least by inference, with emphasizing recrystallization to the total exclusion of the alternative process. Scientists, like other men, like to classify and pigeon-hole views under simple and definite designations, leaving out qualifications which would tend to make the classification more difficult to state. This has made the problem seem more definite and simple, but has tended to obscure the fact that the disagreement is primarily not one relating to essential facts, but one of

[1] Barrell, Joseph: Geology of the Marysville Mining District, Montana; a Study of Igneous Intrusion and Contact Metamorphism, *Professional Paper No.* 57, *U. S. Geological Survey* (1907); Leith, C. K., and Harder, E. C.: The Iron Ores of the Iron Springs District, Southern Utah, *Bulletin No.* 338, *U. S. Geological Survey* (1908).

emphasis. The relative importance of processes seems to vary greatly in different districts. Until many more contacts have been carefully studied, agreement as to the relative importance of processes in general is perhaps not to be expected.

Evidences for recrystallization, briefly summarized and without qualification, are as follows:

1. So far as there is recrystallization it relates mainly to part of the silicate minerals and the residual carbonates of the contact zone. By no stretch can it explain the metallic minerals. The development of silicates from the lime or magnesia carbonates involves the elimination of all the carbon dioxide and some of the lime and magnesia, with recrystallization into silicates of part of the lime and magnesia together with other impurities which may be present, such as silica, iron, kaolin, and other substances. In certain districts the composition of part of the silicate zone (usually the outer part) corresponds approximately to the composition of the original carbonate rock, minus carbon dioxide and a part of the lime and magnesia. No analyzed samples have shown exact correspondence. It would be difficult to find exact correspondence because of later replacements, because of original variation of beds, and because of difficulty of confining sampling only to the recrystallized zone; but in some cases there is a remarkable tendency toward the constancy of silica-alumina ratios in comparison of original limestones and the supposedly recrystallized phases. The ratio is not absolutely maintained, but the variation in the silica-alumina ratio is slight as compared to the variations which are found in the parts of the contact zone in which materials have been clearly introduced. It would be remarkable if substances brought in at random from magmatic sources should approximate so closely the composition of residual impurities of limestone. A most striking case of this, which has been worked out quantitatively on a large scale, is the contact metamorphism of cherty iron carbonates by great masses of gabbro in the Lake Superior country. Here the iron-silica ratio of the altered phase corresponds almost exactly with that of the original carbonate rock, the change being merely an elimination of carbon dioxide. Analyses have been taken from many thousands of samples brought up in drill cores and in continuous sections across the formation.[2]

2. Secondary silicates of contact zones have often been found to be localized along cherty beds or around fragments of chert in the carbonate. Again the Lake Superior region furnishes an illustration in that cores brought from a depth of many hundred feet, where there has been no chance of surface alteration, and at some distance from the intrusive, show the development of secondary iron silicates, principally grünerite, along

[2] Van Hise, C. R., and Leith, C. K.: The Geology of the Lake Superior Region, *Monograph* LII, *U. S. Geological Survey*, p. 546 (1911).

contact of carbonate and siliceous layers, in a rock which is so dense there is little or no possiblity for the introduction of these substances from without. The ratio of silica to iron has been almost exactly maintained. And yet these are clearly developed under influence of intrusives.

3. The similarity of secondary silicates in limestones and marbles far removed from igneous contacts to some of those developed at contacts is also suggestive evidence of recrystallization along contacts.

4. Elimination of carbon dioxide and lime is postulated under either hypothesis, "replacement" or "recrystallization." The natural consequence of elimination is recrystallization of the residual materials, whether or not these are supplemented by accessions from magmatic sources. There is no good *a priori* reason why accessions should always exactly balance elimination, especially when the physical conditions of intrusion are considered—and there is no satisfactory quantitative proof that they have. Under physical conditions which have been supposed to attend the earlier stages of intrusion of a magma it is easy to conceive of pore spaces caused by elimination to be closed as fast as formed, thereby reducing volume, and, in fact, it is usual to conceive of the pressure actually being a factor in the elimination. Under the replacement hypothesis we find it necessary to assume that whatever the pressure conditions were, whether those tending to close up openings or not, the materials taken out and those introduced were delicately balanced in volume; that just enough is introduced in any one place to take the place of that which is left.

5. The reduction in volume required by the recrystallization hypothesis cannot in most cases be disproved. So far as original textures are retained, as they are in some districts, then it is possible to infer, rightly I think, that the volume has not been considerably reduced, and, therefore, that elimination has not taken place except by equivalent introduction of new materials. But the supposedly recrystallized substances are usually in a structurally amorphous zone which may well be the residual of an original mass many times greater. Opponents of the recrystallization hypothesis have argued that the necessary elimination of substances, and consequent reduction of volume, is too large to be reasonable. The reasonableness or unreasonableness of this is a difficult point to argue. It is largely a matter of personal opinion. To me it does not seem inherently improbable. Elimination is equally necessary to the alternative hypothesis of introduction of the materials from magmatic sources. Without elimination it is necessary to assume an enormous increase in volume to take care of enough new material to give an average composition of the contact phase.

6. Discrimination of two phases of contact metamorphism is essential to an interpretation of conditions of formation of contact zones.

Students of contact metamorphism may to much advantage study

the mathematical theory of heat conduction as applied to an igneous contact. We are indebted to Professors Ingersoll and Zobel[3] for an illuminating discussion of the principles of heat flow from an igneous rock of given dimensions into surrounding limestone. Their conclusions, which seem to be well based on general physical principles, are especially interesting in showing the remarkably slow progress of a heat wave into the limestone. Quoting from Ingersoll's and Zobel's discussion of a hypothetical case:[4]

"The conclusions to be drawn from the curves are: first, that the cooling is a very slow process, occupying tens of thousands of years; second, that the boundary-surface temperature quickly falls to half[5] the initial value and then cools only slowly, and also that for a hundred or more years there is a large temperature gradient over only a few meters and a very slow progress of the heat wave; third, the maximum temperature in the limestone, or the crest (so to speak) of the heat wave, travels outward only a few centimeters a year. The mass behind it will then suffer a contraction as soon as it begins to cool, and the cracking and introduction of mineral-bearing material is doubtless a consequence of this."

Especially significant is the inference from the curves of heat flow that in advance of the heat wave the rock is tending to expand, therefore, to be compressed, whereas, following it during a long period of time there is contraction and the development of cracks. These conditions seem to favor two principal phases of contact metamorphism.

As the igneous mass advances into limestone it presumably is exerting mechanical pressure, judging by deformation at some contacts, and at the same time sending out heat into the surrounding rock, which, itself, increases the pressure. It is difficult to avoid the conclusion that for a time at least the adjacent rocks are under considerable pressure and that this pressure would favor elimination. It does not seem at all necessary or probable that under pressure this elimination should be immediately followed by introduction of other substances from the magma, or, putting it in another way, that substances from the magma should always so closely follow elimination as to replace molecule by molecule the original materials and thereby prevent any reduction of volume. As the crest of the heat wave advances into the surrounding limestone, lower temperatures follow, with the result that there is contraction and the development of openings. This contraction may effect not only the lime-

[3] Ingersoll, L. R., and Zobel, O. J.: *An Introduction to Mathematical Theory of Heat Conduction with Engineering and Geological Applications* (Ginn & Co., 1913).

[4] *Loc. cit.*, pp. 128 to 129.

[5] Strictly speaking, the initial temperature of the boundary surface would be somewhat higher than this; for the conductivity of hot igneous rock is considerably greater than that of the cold limestone although, in order to be able to handle the problem, we have had to consider their thermal constants as the same. The temperature of the boundary surface for the first hundred years or so could best be estimated from equation (49) of Art. 80. The error introduced by assuming the diffusivities to be the same becomes less and less as the cooling proceeds.

stone but the intrusive itself. Into such openings the magmatic solutions may freely enter, and there are deposited the ores and some of their gangue materials. At the same time these solutions may replace the materials of the surrounding rock to a greater or less extent.

That contact metamorphism of limestone has been accomplished in two successive phases has been pretty well proved at certain contacts. It seems probable that when attention is directed specifically to this feature it may be found at others. The first phase seems to be characterized by the production of an amorphous, homogeneous, silicate mass, not definitely associated with fissures. In some cases this is discriminated sharply from, in other cases it merges gradually into, a phase characterized by sulphides and other ore-bearing minerals with their gangue materials, which occur much more largely in fissures. These fissures may often be seen to traverse the silicate zone of the first phase. The minerals of the later phase, both because of their composition and because of evidence of their transportation, cannot be regarded as recrystallizations of materials in place. They afford evidences of introduction from magmatic sources.

The two phases of alteration may merge one into the other both in time and place. The later phase may be expected to obliterate to some extent the earlier phase. Ordinarily the later minerals differ from the earlier ones, but certain silicates, quartz, and other minerals, may be common to both.

I do not attempt to cite evidences in detail from specific localities. My purpose is rather to outline the case for recrystallization. W. L. Uglow,[6] in a recent paper, has cited evidences and references in some detail and in a forthcoming paper will cite more. I do not contend that all contacts will be proved to show important recrystallization or even that all of the illustrations cited in Mr. Uglow's paper are valid ones. I hold only that recrystallization has been proved in enough places and to sufficient degree to warrant its citation as a usual accompaniment of the process of introduction of magmatic materials. In some cases it seems to be important. In others evidence of it is slight or absent, though in these cases it may be masked by the introduction of materials in the second phase of contact metamorphism. Its complete absence in the nature of the case is difficult to prove quantitatively. Advocates of the recrystallization hypothesis have not, so far as I know, held that it was sufficient to explain all contact phenomena. They have offered it only as an explanation of one phase of contact alteration. Failure to consider this hypothesis involves failure to consider the possibilities of a two-phase alteration which seems to me to be the probable key to much contact metamorphism. With the majority of economic geolo-

[6] Uglow, W. L.: A Review of the Existing Hypothesis on the Origin of the Secondary Silicate Zones at the Contacts of Intrusives with Limestones, *Economic Geology*, vol. viii, No. 1, pp. 19 to 50; No. 3, pp. 215 to 234 (Jan., Apr., 1913).

gists, I recognize the conspicuous evidence of the introduction of magmatic materials. My plea is that this hypothesis be not magnified to the exclusion of the recrystallization hypothesis. Quantitative studies of contacts based on adequate sampling have unfortunately been rare. Without them, conclusions can be only qualitative and not exclusive.

Discussion

Waldemar Lindgren, Boston, Mass.—I think geologists should be careful how they associate with mathematicians. Now, what these men have done is simply to take two adjoining bodies, one very hot and one very cold, and calculate the conditions resulting. That is not the idea at all. The idea is that the limestone receives the emanations from the magma, and that these magmatic emanations pass through it almost like water goes through a sponge, so that, reasoning from that point of view, I do not think that this mathematical calculation has very much bearing on it, because the emanations would find fissures and penetrate long distances that would upset the whole calculation. The penetration of the emanation would be very much more rapid in any case than would be the diffusion between two bodies adjoining, without any action on each other except by the heat.

James F. Kemp, New York, N. Y.—The igneous rocks sometimes show the reflex action of the limestone in having garnets in epidote.

I was interested in reading Professor Leith's paper in the emphasis laid on the delicate balance of the materials that enter the limestone, with the result, it would seem, that one could reply that when the material ceases to come from the igneous rock the garnet ceases to form.

Mr. Lane raised the point, inferentially, that Mr. Lindgren cannot show the effect of the limestone of the igneous rock, but I believe he has shown such effect in that he mentioned garnets and epidotes in the igneous rock itself.

Professor Leith has made an objection to the contribution from the igneous rock, because of the delicate balance between the recrystallized materials and the contributions, but, of course, if the garnets are produced from the limestone by additions of silica and iron, their crystallization would cease when the contributions stopped. A balance would necessarily, therefore, be established. I presume, however, that Professor Leith's point was based upon this consideration—he believes the limestone to be calcined by the igneous rock, but that limit itself would result in greater quantity than is present in the silicate.

John D. Irving, New Haven, Conn.—For reasons which it seems unnecessary to give at length I believe that the lime silicates which develop at the contacts of intrusive igneous rocks with limestone are formed

almost entirely with the aid of contributions of silica and limestone derived as emanations from the intrusive magmas. The formation of such silicates, however, demands the elimination of a large quantity of carbon dioxide, inasmuch as this compound does not appear to any extent as a constituent of the lime-silicate zones. While there are, of course, many ways in which carbon dioxide can be expelled in gaseous form and escape through fractures and fissures to the surface, it is conceivable that under conditions of high temperature and pressure, such as have accompanied deep-seated intrusions, fissures and fractures for the escape of carbon dioxide should have been either wanting or insufficient in number. The elimination of the carbon dioxide under these circumstances offers a problem of some difficulty. I would like to learn from Mr. Lindgren whether he has any suggestions to offer in regard to this point.

Safeguarding the Use of Electricity in Mines

BY H. H. CLARK,* WASHINGTON, D. C.

(New York Meeting, February, 1914)

ELECTRICITY must be safeguarded everywhere that it is used. The conditions that exist underground make the use of safeguards more essential there than almost anywhere else.

Electric Shock

Electric shock is the greatest danger in connection with the use of electricity in mines, because conditions existing underground are so favorable to its occurrence. Men are often obliged to work in more or less uncertain light near bare wires that are carrying dangerous potentials. The fact that the men are standing on the earth practically connects them to one terminal of the electric generator.

The most dangerous piece of electrical equipment underground is the trolley wire. It is necessarily bare and extends for long distances throughout a mine, often less than a man's height from the track rail. Sometimes the making up of trips of cars must be done near low-hanging trolley wires. All bare wires offer the same danger that trolley wires do, although not to the same extent.

Apparatus that has accidentally come in contact with the ungrounded side of an electric circuit is almost as dangerous as the trolley wire. A severe and even fatal shock may be obtained by coming in contact with the frame of a motor or a switch box that has become charged with electricity, or "alive," as it is usually termed. It is also possible to obtain shocks from the frames of locomotives and cars if track sanding, poor bonding or a similar cause has put a high resistance to earth in the path of the current.

Fires Caused by Electricity

The danger from fires caused by electricity arises principally from defective installation and careless upkeep or from injuries to equipment resulting from falls of roof or similar causes. Fires may be started by unrelieved short circuits, or grounds, by the blowing of open fuses, and by the overheating of resistances. Incandescent lamps can produce heat enough to ignite combustible materials if the dissipation of the heat from

* Non-member.

the bulbs of the lamps is allowed to become restricted. The fire danger is more remote than the shock danger, but it may affect a larger number of men.

Explosions Caused by Electricity

Explosions may be caused by the ignition of explosives, gas, or coal dust. Accidents due to the ignition of explosives by electricity are of two kinds: Those that occur while handling and transporting explosives near electric circuits, and those that are incident to the detonation of explosives by electrical means.

Transporting Explosives.—Some very mysterious accidents of the first kind have occurred, but I believe that most of these have been caused by hauling explosives in metallic packages, or else so near the locomotive that flashes or sparks from the trolley wire have come in contact with the explosives.

Electrical Shot-Firing.—Electrical shot-firing accidents are usually caused by the premature ignition of shots after holes are charged. It is not the best practice to shoot electrically under conditions that require one side of the detonating circuit to be connected to the earth, because wherever grounded systems of power distribution are used unexpected differences of potential exist in the earth in the vicinity of such circuits. If, therefore, one side of the detonator be purposely grounded an accidental ground on the other side may connect the detonator across a potential sufficient to cause ignition. Premature ignitions have been reported which seemingly have been caused by the conditions just described.

Gas Ignition by Electricity

For all practical purposes it may be assumed that sparks that occur around such apparatus and circuits as are used for power and light in a mine are capable of igniting gas. The ignition of gas by incandescent lamps has been investigated by the Bureau of Mines quite thoroughly with carbon filament lamps and to a lesser extent with tungsten filament lamps. The results of the investigation seem to indicate that certain of the larger sizes of carbon filaments will ignite gas and that tungsten lamps of 25 watts or more are almost certain to ignite gas when broken.

Ignition of Coal Dust by Electricity

The study of the ignition of coal dust by electric arcs and electric flashes has been carried on to some extent by investigators in Europe. The results of their experiments indicate that electric flashes can ignite coal dust suspended in the atmosphere. The Bureau of Mines has planned similar investigations to proceed as soon as funds are available.

Underground Conditions are Favorable to the Occurrence of Accidents

Every one connected with mining work knows that the natural conditions surrounding underground installations of any character are such that accidents are likely to occur and this is especially true of electrical installations. It is not necessary to rehearse all of these conditions, as every one is familiar with them.

Prevention of Electrical Accidents

The knowledge of the existence of danger requires that steps be taken to prevent accidents. It is certain that haphazard methods will not solve the safety problem any more than they will solve the haulage problem or the ventilation problem. Measures to be effective must be well considered.

Unfortunately, the safety problem cannot be solved on just the same basis as the ventilation problem, for instance. Safety cannot be calculated mathematically by the use of constants obtained from experience. Definite data as to what will produce safety under the complex conditions involved are not available. It has seemed to me that a good way to begin is to outline methods that, so far as we can see, will surely produce safety, and then to determine how these methods can be put into practical operation. For the sake of discussion, therefore, I will make the following five suggestions for reducing the number of accidents due to the use of electricity in mines:

1. Remove contributory causes.
2. Remove from the vicinity of electrical apparatus all elements susceptible to its influence (gas, dust, explosives, combustible material).
3. Keep the electric current where it belongs.
4. If, under certain circumstances, the current cannot be entirely confined, at least limit the area of its activity by the use of protective devices.
5. Insure a high factor of safety by:
    (a) Selecting materials and apparatus with care.
    (b) Installing equipment in a strictly first-class manner.
    (c) Inspecting equipment frequently and thoroughly.
    (d) Maintaining it in good condition at all times.

Concerted Action

Suppose that it is agreed that these measures (or any others) will solve the problem, the next question is how to put these into effect. To get the best results the co-operation of all concerned must be secured. There may be, no doubt there will be, many ways of getting the desired result. Each one has his own experience and his own views based thereon, but disorganized forces acting along different lines will not produce the

results of concerted action along lines that, in the light of combined experience, may be agreed upon by the majority of those interested. The greatest benefit can be derived if, from the great mass of experience of the many who are interested in safeguarding electricity in mines, a definite plan of common action can be evolved and a code of rules laid down, which in the opinion of all will bring about the safe conditions that all desire. If such a code were put into effect generally, its weak points could be strengthened from time to time by the common experience of many engineers and operators, who would be trying out the same requirements under various conditions.

Co-operation of Mine Electricians

My experience and that of others reported to me leads me to believe that a code of rules would be welcomed by the underground electrical men who are to put them in force. These men, as a whole, desire to do things in the proper way and would be glad to have the proper way pointed out to them. They enjoy arbitrary criticism as little as any one, but I believe that most of them would appreciate constructive criticism and would co-operate in carrying out suggestions made by people in whom they have confidence. If such a movement could be started its difficulties would grow less as time went on, because the power of tradition is nearly as strong for good as it is for evil. The average electrical worker on the surface knows how to install electrical apparatus, because he has been educated and guided by the Underwriters' rules which have established a tradition for good work which cannot lightly be set aside.

I wish to emphasize that the solution of this problem rests largely with the underground electrical worker. If good men are selected for this position and are properly instructed and encouraged to look out for the safety side of the electrical work, the problem is practically solved.

Electricity as a Safeguard

I believe that we shall see the day when electricity, so far from being considered a menace to those who work in mines, will be regarded as a means of safeguarding life and property and reducing the accidents that heretofore have occurred. Already there are certain electrical devices whose adoption and general use will make for safety. Among these are the telephone, the electrical shot-firing device, the storage-battery locomotive, and portable electric mine lamps. If the storage-battery locomotive can be developed so that it can successfully displace the trolley-wire locomotive, the greatest single cause of electrical accidents, the trolley wire, can be withdrawn from service at least to a large extent.

Portable Electric Lamps.—The engineers of the Bureau of Mines and

other engineers believe that the use of portable electric lamps will do much toward reducing the number of accidents in mines, and with this in mind we are making every effort to assist in the development and urge the adoption of these lamps. Based upon the undoubtedly true premise that the battery is the part of a portable lamp equipment most difficult to develop, there has been a tendency to lose sight of certain other necessary features of portable electric lamps. The first consideration in the design of these lamps is to have them safe so that they will not ignite gas and so that they will not become extinguished and leave a man in the dark, but while these points are indispensable it is equally important that the lamps shall be designed so that they will be acceptable to the men who are to carry them.

Portable electric lamps must be a compromise between several more or less opposed requirements. The fundamental considerations of lamp capacity are the maximum allowable weight of battery, the minimum allowable amount of light, the minimum allowable time of burning, and the minimum allowable life of lamp bulbs. These factors are all interdependent and must be properly proportioned in order to produce an acceptable net result. Other factors must also be kept in mind. Bitter experience with gas explosions led the early English miners to abandon the comparatively brilliant light of the torch for the feeble phosphorescence of fish scales and the scarcely less feeble scintillations of the steel mill. While our modern, ventilated coal mines are probably much less gassy than the unventilated mines of the thirteenth century, nevertheless safety is just as essential now as it was then, and it has been proved that miniature electric lamps can ignite gas if broken under certain conditions obtainable in practice. Therefore, portable electric lamps should be provided with proper safeguards.

Acting upon the principle that the greatest progress can be made by common efforts to the same end, the Bureau has attempted to further the cause of the portable electric lamp by acting as a sort of "go-between" for the miners and the manufacturers in the work of preparing specifications that will represent the kind of lamp that will give the service required by the miners. I wish here to acknowledge the great assistance that the manufacturers have given to the Bureau, and to state that they have at all times manifested that spirit of co-operation without which progress is impossible.

The Bureau would also like the co-operation of this Institute in the matter of examining and criticising these specifications, which will be sent to any member interested.

Discussion

George S. Rice, Pittsburg, Pa.—On behalf of the mining division of the Bureau of Mines, I want to heartily concur in what Mr. Clark has

said, and to emphasize that in the introduction of the miner's portable electric lamps of permissible type there will be a very great gain for safety, not alone in coal mining, where there is a possibility of the ignition of fire damp, but also in metal mines, where there is a possibility of causing fires through open lights. As the matter stands at the present time, it may be some time before we can expect to see the open lamps in metal mines supplanted, but I hope it is not so far off in the case of either gaseous or non-gaseous coal mines. Safety lamps, as compared with the electric cap-lamp, are cumbersome and present elements of danger in careless hands. The proper place in coal mines for safety lamps is, as I see it, only for the testing of gas, and it may be that in the near future we will have better means for testing for gas than this.

The number of accidents that occur from open lights in coal mines is surprising. Unfortunately, the mining statistics which are gathered by the various States do not bring this out clearly, but in Great Britain in certain districts where they gather figures giving the cause of accidents from explosions and fires in open-lamp mines and safety-lamp mines, 90 per cent. of such accidents have arisen from the use of the open light.

In the matter of the introduction of electricity in mines, although it has proved of great commercial benefit, I think it must be admitted that it has increased the hazards of mining, in the case of coal mines, from the ignition of fire damp, by the trolley or grounding of power lines, and in both the coal and metal mines, as a source of ignition of fires. But electricity is so convenient we would not like to be without it, and the best thing to do is to make it as safe as we can.

I think that one of the points which will need the attention of the electrical engineers is as to the use of insulation for underground power wires. Abroad that is required. In this country it is not, and it has been constantly brought to my attention, from the reports of accidents, that if the wires had been insulated perhaps the accident would not have occurred. I have in mind one recent investigation which developed that in all probability an explosion of fire damp was caused by a wire grounding from a piece of slate having fallen on the bare power line, and carried it down so that it grounded against the rail.

There is one point I might speak of in Mr. Clark's paper, which I think, perhaps, might give an impression different from what he meant. He referred to the fact that the Bureau would take up tests of the ignition of coal dust when we had funds. He undoubtedly meant the study of different electrical means of igniting coal dust, because for the last three or four years the Bureau has been gathering samples of coal dust in coal mines throughout the country and testing them in laboratory apparatus which employs electricity for ignition, for determination of their relative inflammability. Regarding the latter we have not yet reached conclusions, but do find very marked variations in inflammability in different

coal dusts, apart from the ash contents. Sometimes coal dusts from the same district and giving about the same approximate analysis differ very markedly. The physical characteristics, the grouping of the molecules of the coal, and the relative presence of spores all may be factors. The interrelation of the chemical constituents is very complicated. The nearest parallel to the comparative inflammability I can observe is in the relative heat value of the coal, rather than in the presence of oxygen as a constituent of the coal or in the different proportions of its hydrocarbons, with the exception that Pennsylvania anthracite dust is not explosive. The study is a very useful one in following up the propagation of mine explosions. For example, in the case of a recent disaster in New Mexico, we had samples gathered at all the points where the explosion died away, and it is very interesting to see that the results in these laboratory inflammability tests compare very closely with relative violence or checking of the explosion in the mine in the respective districts where the samples were gathered. On a large scale we make somewhat similar tests at the experimental coal mine near Pittsburg, in explosion experiments. Different mixtures of dust are tried, an inert dust being mixed with the coal dust, to observe how much the inflammability is reduced.

E. Gybbon Spilsbury, New York, N. Y.—I would like to ask Mr. Clark how far the development of the electric lamp has been carried, and also if the weight has been reduced in comparison with the weight of the ordinary safety lamp used in the coal-mining district.

H. H. Clark.—In reply to Mr. Spilsbury's question, with reference to the development and the weight of the electric lamp, I will say that the development of the electric lamp is now in its infancy. We have been at work in collaboration, so to speak, with the manufacturers something over a year and a half. I do not know that we can say that any lamp is completely developed, although some are very nearly so, and I believe that there will shortly be on the market a practical, efficient, and safe lamp, that will meet the requirements of the authorities, that will weigh in the vicinity of $3\frac{1}{2}$ lb., and that will give a good deal more light than the safety lamp will. The light will also be disposed in a better way, so that a man can easily see the roof or the sides or the floor of the mine, or concentrate the light by being able to put his head closer to the part he wishes to see. The development is proceeding rapidly, when everything is considered.

There are a number of different manufacturers working on the problem, and all of them seem to be making headway; they will finally develop an article that will be strong, substantial and give a satisfactory amount of light, a lamp which will stand up under service.

E. Gybbon Spilsbury.—What is the weight of the ordinary safety lamp?

H. H. Clark.—I am not positive, I think it is about 3 or $3\frac{1}{4}$ lb.

G. S. Rice.—When the safety lamps are made of aluminum, they weigh from $3\frac{1}{2}$ to 4 lb., but the ordinary miners' safety lamp is made of brass and this weighs from 5 to $5\frac{1}{2}$ lb.

The fact might be brought out that a type of electric lamp which seems to be favored in this country is, not the hand lamp, but a cap type of lamp, with a cord going down at the back to the battery, which is carried by a waist belt, thus presenting advantages over the safety lamp carried by hand, which makes a man one-handed, or, if he hangs the lamp from his clothing or belt, there is danger of breaking the glass chimney of the safety lamp.

B. F. Tillson, Franklin Furnace, N. J.—I would ask Mr. Clark whether the light in the lamp to which he refers is supplied by a storage battery, or is the lamp of a type which was more recently developed, in which electrodes of carbon, zinc or other metals are used in primary batteries. There has come to my attention a lamp which uses different electrodes, which electrodes require replacement each shift. That type of lamp seems to be lighter than the storage-battery lamps which we have tried.

We have tried lamps in metal mining chiefly for the use of men in the powder house and of the men who are priming the sticks of powder, so as to avoid any naked lights or lanterns under such conditions. The lamps of a storage-battery type which we have tried have been too heavy for cap lamps or workmen's lanterns. We have seen some in which they used electrodes, and changed the electrodes each shift, which were lighter. I do not know what would be the limit in the reduction of weight in future designs of a primary-cell type.

H. H. Clark.—The lamp I had more particular reference to was a lamp of the storage-battery type. There have been attempts made to develop a primary-battery lamp, and I hope they may be successful eventually. The primary-battery lamp will probably be a little lighter than the storage-battery lamp.

The lamp I had in mind when speaking a few moments ago was the cap type of lamp which is used by most of the miners in the Western Pennsylvania field. The hand type of lamp will probably weigh more than the cap type of lamp, but will give more light than the cap type of lamp. The casing will be made heavier. Probably an electric hand lamp will weigh from 4 to 5 lb., depending on the amount of light the lamp is to give, or the length of time that the lamp is required to produce that light.

The cap type of lamp I refer to as weighing $3\frac{1}{2}$ lb. was a storage-battery equipment, although, as Mr. Tillson suggests, there are one, or possibly two, primary-battery lamps which are now in the midst of their development.

The Application of Electric Motors to Shovels

BY H. W. ROGERS, SCHENECTADY, N. Y.

(New York Meeting, February, 1914)

THE first steam shovels used in this country were built by the Otis Company, of Boston, about 50 years ago, but as they were of very crude construction and rather unsuccessful only a few were built.

For possibly 10 years prior to 1884 successful steam shovels were made and used on certain classes of work, but it was not until that time that they were manufactured in quantities and began to play an important part in all classes of excavation. From that time up to the present day there have been gradual but continuous improvements on the original shovel, not only in the mechanical construction, but also in the design of boilers and engines which are best adapted to this class of service.

In proposing a change from steam to electric operation we have to deal with a steam equipment which has not only proved its worth but has probably reached its highest stage of development and efficiency. That the electric shovel is a possibility cannot be denied, as at present from 12 to 18 shovels are in operation in this country. These shovels may be divided into three classes: the friction electric, which is operated by a single constant-speed motor with friction clutches; the three or four motor direct-current equipment, and the three or four motor alternating-current equipment. It is the second and third classes that I wish to deal with, as the first class does not compare favorably with the steam shovel so far as speed is concerned, although it may be operated as cheaply.

There is probably no other class of machinery that presents a duty cycle as severe as that of the shovel, which is very short, varying from 7 to 12 sec. on the hoist, from 7 to 12 sec. on the thrust, and from 10 to 18 sec. on the swing, making a complete cycle in from 17 to 30 sec., and the motor to meet these requirements must have a sufficiently low armature inertia to permit of rapid acceleration and quick reversals under small power. It should also be a motor of rugged design, as it must be subjected to severe overloads and shocks and frequent reversals. This is especially true of the hoist motors and, to a lesser degree, of the swing motor; the thrust motor being practically stalled during the digging operation, although it may revolve or overhaul, according to conditions, and is operated at full speed only after the hoisting operation is completed.

Fig. 1 is a view of a 30-h.p. motor operating the thrust on a 65-ton electric shovel.

In the case of the hoist, considerable advantage may be gained by using two motors of small capacity instead of one large motor, as the power required for accelerating is much less. For example, assume a shovel that requires a 150-h.p., 425 rev. per minute motor for the hoisting operation; this motor requires 117 h.p. torque to bring it to speed in 1 sec., whereas if we substitute two 75-h.p., 500 rev. per minute motors in place of it, each motor requiring 32.3 h.p. torque to bring it to speed in 1 sec., or 64.6 h.p. torque to bring both motors to speed in 1 sec., there would be a saving of 45 per cent. in the power required to accelerate the motors

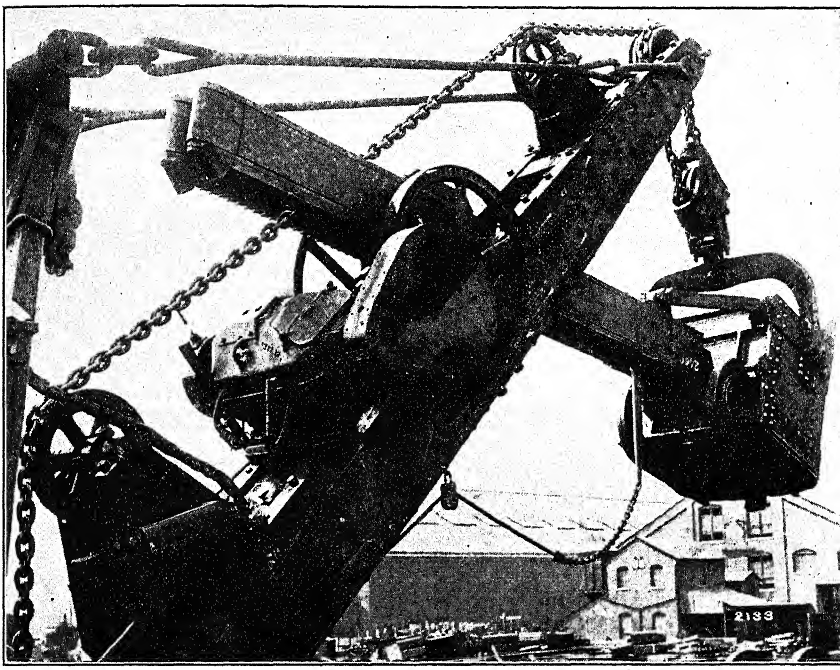

FIG. 1.—30-H.P. SERIES MOTOR AND CONTROLLER OPERATING THE THRUST ON A 65-TON ELECTRIC SHOVEL.

alone. A plan showing the best method of locating and gearing motors to hoist and swing machinery is given in Fig. 2.

Although there may be some demand for equipments to operate on direct-current circuits, the greater part will be required to operate on alternating-current circuits at 60 cycles, and the question naturally arises as to whether the direct-current series motor with motor-generator set or the alternating-current motor with transformers should be used.

This question has been the subject of considerable discussion and there still exists a difference of opinion as to whether the direct-current series motor or the slip-ring induction is best adapted to this service. As a means of comparison the accompanying curves, Fig. 3, have been plotted between speed and torque, and between speed and kilowatts input, on two 80-h.p., 500 rev. per minute, direct-current series motors operating in multiple and two 150-h.p., 450 rev. per minute, 60-cycle, slip-ring induction motors operating in multiple. These curves are based on a gear ratio of 3.31 to 1.0 on the direct-current motors and a gear ratio of 1.45 to 1.0 on the induction motors, the torque values given applying to

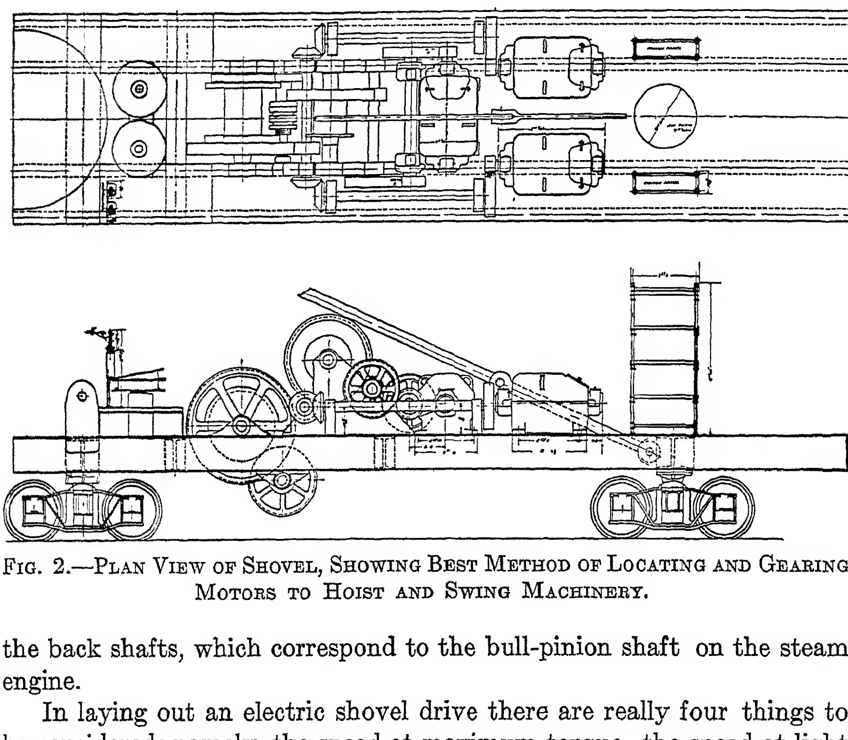

FIG. 2.—PLAN VIEW OF SHOVEL, SHOWING BEST METHOD OF LOCATING AND GEARING MOTORS TO HOIST AND SWING MACHINERY.

the back shafts, which correspond to the bull-pinion shaft on the steam engine.

In laying out an electric shovel drive there are really four things to be considered: namely, the speed at maximum torque, the speed at light load, the power required by the motor, and the gear ratio. An increase in the gear ratio results in a decrease in power at both light and heavy loads, an increase in the speed at heavy loads, and a decrease in the speed at light loads, and taking all of these variables into consideration the gear ratios given above seem to be the most satisfactory.

The direct-current series motor has the characteristics of the steam engine, in that it gives its heaviest torque on starting, speeds up under light loads, and slows down under heavy loads. It is much easier to control and requires considerably less apparatus, in so far as the control is concerned, than the alternating-current equipment. This character-

istic is clearly shown on the curve, which represents a five-point control, four of these points being used to cut out the armature resistance and the fifth to weaken the series field, which results in a very high light-load speed.

With the alternating-current slip-ring motor it is impossible to obtain the maximum torque on starting; and the light-load speed, which is very important, is limited by the synchronous speed. The only means of improving this disadvantage is to reduce the gear ratio or use a higher-speed motor, either of which methods would mean an increase in the

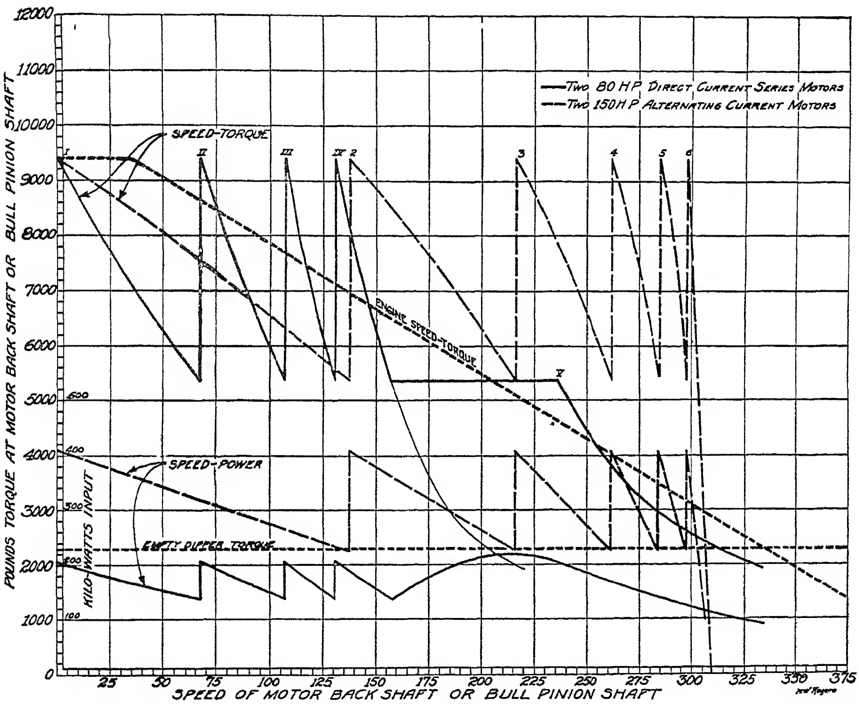

FIG. 3.—COMPARISON OF SPEED-TORQUE AND SPEED-POWER CURVES ON DIRECT-CURRENT SERIES AND ALTERNATING-CURRENT SLIP-RING MOTORS.

capacity of the motors and an increase in the inertia, which would result in an increase in the power required and a slower acceleration, both of which are undesirable. This feature will be appreciated from the following data applying to the motors used in plotting the curves.

	Total WR²	Diameter Rotor Inches	Per cent. Torque to bring to Speed in 1 Sec.
Two 80-h.p., 500 rev. per min.—series	444	16	43
Two 150-h.p., 450 rev. per min.—induction	2,480	30	98

Under this condition the natural result is a much larger kilovolt-ampere capacity in transformers for the induction motors than kilowatt capacity of motor-generator set for the direct-current motors.

The saving in operating expense of the electric shovel over the steam shovel will depend somewhat upon the comparative cost of coal and electric power and will vary for different localities, but it should be remembered that the electrically operated shovel eliminates the fireman, the watchman, the coal passer, teaming for ½ day, the use of water, and considerable waste. The natural increased wear and tear of parts having a transverse motion as compared with those having rotary motion and

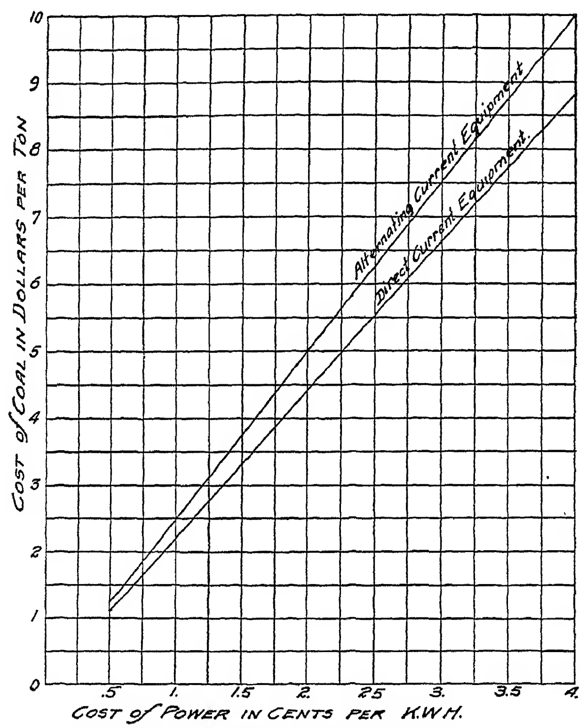

Fig. 4.—Curve Showing Comparative Cost of Coal and Electric Power.

the elimination of boiler trouble should also be considered. Fig. 4 shows graphically the comparative cost of coal and electric power.

As an illustration consider a 120-ton shovel which is ordinarily equipped with a 5 cu. yd. dipper and has an average capacity of approximately 2,500 cu. yd. per 10-hr. day. This capacity is based on an average working time of 55 per cent. and an average dipper capacity of 3¾ cu. yd., or 75 per cent.

With a good grade of coal the steam shovel will require approximately 3¼ tons per 8-hr. shift and will make an average of two complete cycles

per minute. For the purpose of comparison, however, the maximum capacity of the shovel is taken; *i.e.*, three cycles per minute. Under these conditions either the steam or the electric shovel will have a total working time during one shift of $8 \times 60 \times 0.55 = 264$ min., during which time it will make $264 \times 3 = 792$ complete cycles, and will handle $792 \times 3\frac{3}{4} = 2,970$ cu. yd. of material.

The direct-current shovel would be equipped with two 80-h.p., 500 rev. per minute, 230-volt series motors on the hoist, one 40-h.p., 550 rev. per minute, 230-volt series motor on the swing, one 60-h.p., 550 rev. per minute, 230-volt series motor on the thrust, and one 150-kw., 900 rev. per minute, 250-volt direct-current generator direct connected to a 225-h.p., 900 rev. per minute, 2,200-volt induction motor, with four-point reversible automatic control on each motor.

The estimated power consumption during each cycle will be as follows:

	Kw-seconds
Hoisting	1,379
Swinging	522
Crowding	547
Total	2,448 = 0.68 kw-hr.

$792 \times 0.68 = 539$ kw-hr. input to the motors per 8-hr. shift, or, taking into account the efficiency of the motor-generator set, 657 kw-hr. per 8-hr. shift.

As the shovel is working only 55 per cent. of the time, the motor-generator set will be running light 45 per cent. of the time, or $8 \times 60 \times 0.45 = 216$ min.

The power consumption on the set when running light will be approximately 16.77 kw.

$$\frac{216 \times 16.77}{60} = 60.4 \text{ kw-hr. loss per 8-hr. shift.}$$

$657 + 60.4 = 717.4$ kw-hr. total power consumption per 8-hr. shift when working under the maximum cycle.

$$\frac{717.4}{2,970} = 0.241 \text{ kw-hr. per cubic yard excavated.}$$

The alternating-current shovel would be equipped with two 150-h.p., 450 rev. per minute, 440-volt motors on the hoist, one 50-h.p., 720 rev. per minute, 440-volt motor on the swing, one 75-h.p., 600 rev. per min., 440-volt motor on the thrust, and three 125 kilovolt-ampere, 2,200–480-volt transformers, with five-point reversible automatic control on each motor.

The estimated power consumption during each cycle will be as follows:

	Kw-seconds
Hoisting	2,040
Swinging	759
Crowding	750
Total	3,549 = 0.987 kw-hr.

792 × 0.987 = 782 kw-hr. input to the motors per 8-hr. shift, or, taking into account the efficiency of the transformers, 796 kw-hr. per 8-hr. shift.

The no-load losses on the transformers will be approximately

$$\frac{216 \times 3.6}{60} = 13.0 \text{ kw-hr. loss per 8-hr. shift.}$$

$$796 + 13 = 809.0 \text{ kw-hr. total per 8-hr. shift.}$$

$$\frac{809}{2{,}970} = 0.273 \text{ kw-hr. per cubic yard excavated.}$$

Labor per shift	Steam	Electric
Shovel runner	$6.00	$6.00
Craneman	4.00	4.00
Fireman	2.50	......
Six pitmen at $1.75	10 50	10.50
One watchman	1.75	......
One coal passer	1.50	......
Teaming (½ day)	2.50	......
Oil and waste	1.50	.75
Total	$30 25	$21.25
Saving, electric over steam	21.25	
	$9.00 per shift.	

For convenience in comparing the costs of operation on steam and electric shovels the costs are all reduced to a day basis.

	Steam	Electric Direct Current	Electric Equivalent Alternating Current
Interest at 6 per cent	$5.20	$7.75	$10.85
Depreciation at 4⅗ per cent	4.03	6.00	8.43
Repairs at 10 per cent	8.66	......	......
Repairs at 6 per cent	....	7.75	10.85
Labor per shift	30.25	21.25	21.25
Total cost per shift	$48.14	$42.75	$51.38

It has been assumed that, owing to weather conditions, delays, etc., the shovel working year consists of 150 days and the above figures are based on this assumption; also that the shovel is only working one shift a day.

If the shovel works three shifts a day instead of one shift a day, the interest and depreciation will remain the same, provided the shovel is kept in repair. It is reasonable to assume that the repairs will increase when working three shifts, but not in direct proportion; therefore this item has been increased 50 per cent.

	Steam	Electric	
		Direct Current	Equivalent Alternating Current
Interest at 6 per cent	$5.20	$7.75	$10.85
Depreciation at $4\frac{2}{3}$ per cent	4.03	6.00	8.43
Repairs at 15 per cent	13.00	....	....
Repairs at 9 per cent	....	11.63	16.28
Labor (three shifts)	90.75	63.75	63.75
Total cost (three shifts)	$112.98	$89.13	$99.31

Disregarding the cost of coal and electric power, the saving of the direct-current shovel over the steam shovel would be $810 per year for one-shift operation and $3,580 per year for three-shift operation.

The alternating-current shovel when working one shift a day would show a loss of $486 per year. On the other hand, if this shovel worked three shifts a day it would show a saving of $2,050.50 per year. Any greater saving than that shown would, of necessity, depend upon the comparative cost of coal and electric power, but as this is variable it can only be shown by means of a curve, as indicated in Fig. 3, or by dealing with each case individually.

Disregarding the cost of fuel, it is evident that the electric shovel is a better proposition than the steam shovel; that the direct-current equipment is far superior to the alternating-current equipment; and that the saving in operating expense will warrant the increased investment.

The control on either the direct or the alternating current equipment is reversible and entirely automatic, all panels being equipped with automatic acceleration, the hoist and crowd panels being also equipped with a "jam" relay which inserts resistance in the circuit in case of very heavy overloads but does not open the circuit, the resistance being automatically cut out again by the same relay when the overload disappears. The master controllers are located similar to the operating levers on a steam shovel, so that a steam operator will be entirely at home on an electric shovel. A view of the interior of a 65-ton shovel, showing the control panel and the air compressor, is given in Fig. 5.

Fig. 6 is a graphic recording ammeter chart showing the current input to a 65-ton electric shovel during six complete cycles of operation. A similar chart for a 120-ton shovel is shown in Fig. 7.

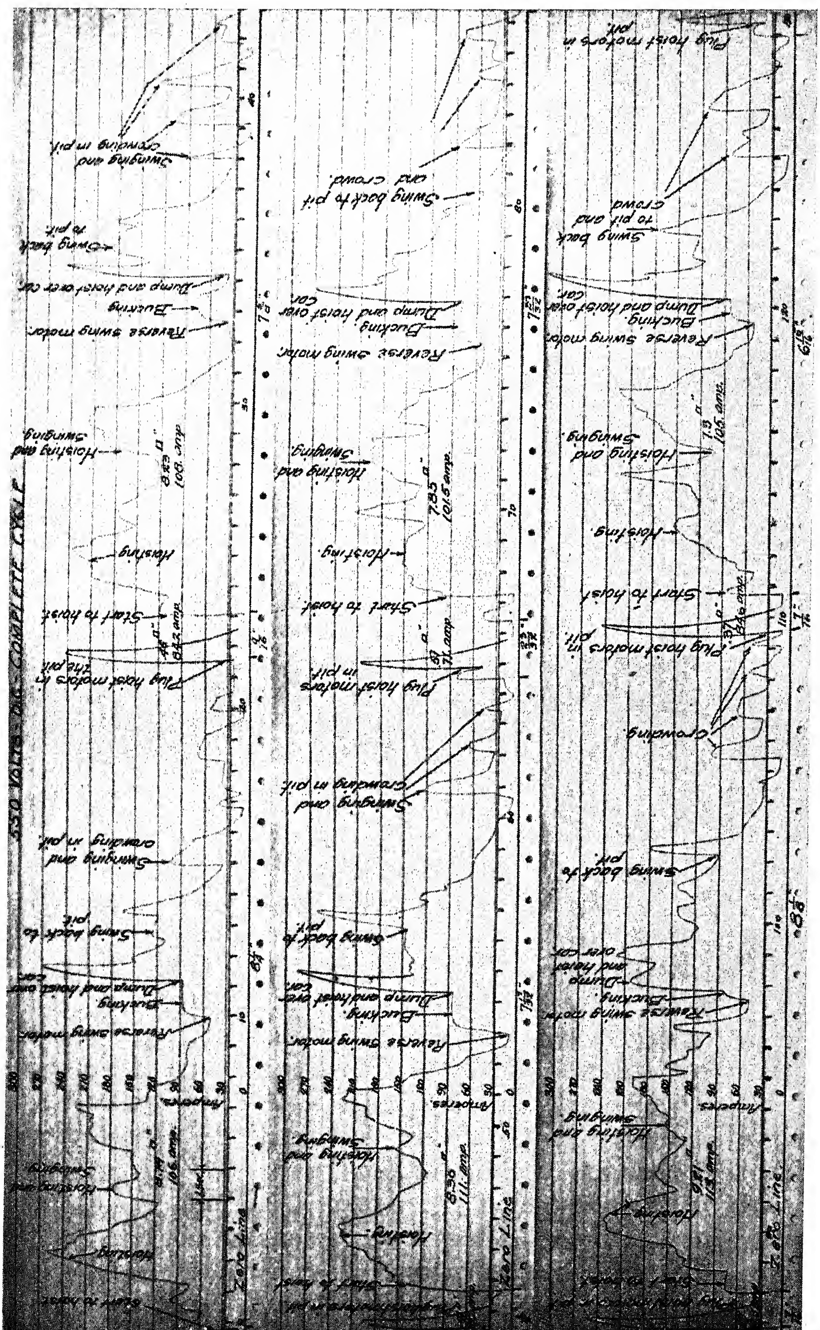

Fig. 6.—Graphic Recording Ammeter Chart of Current Input to a 65-ton Electric Shovel.

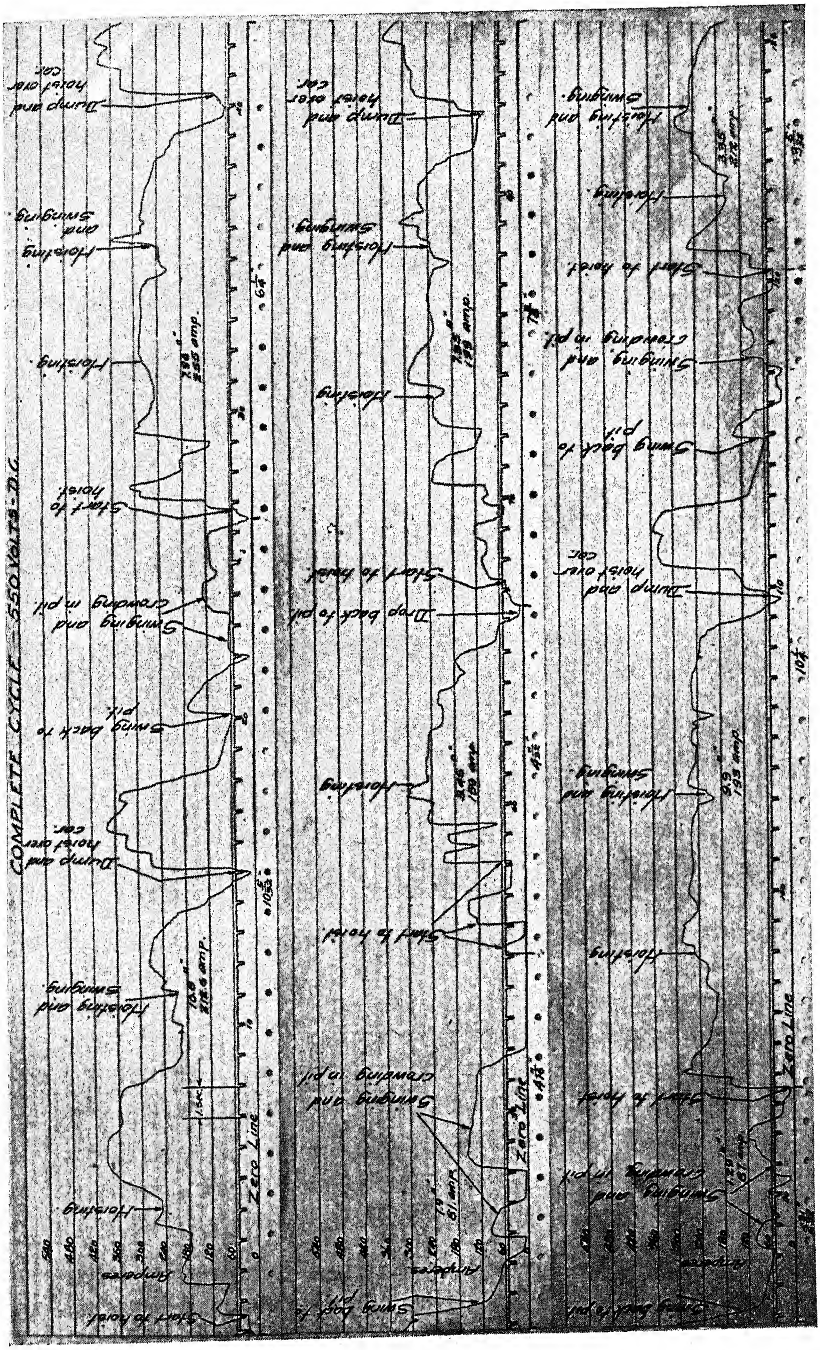

FIG. 7.—GRAPHIC RECORDING AMMETER CHART OF CURRENT INPUT TO A 120-TON ELECTRIC SHOVEL.

In selecting a shovel equipment it should be remembered that although it is possible to operate with alternating current, it is cheaper to use the direct-current equipment, even with a motor-generator set, and have an outfit which more nearly approaches the characteristics of the steam shovel, and has much simpler control apparatus and requires considerably less power to operate it than the alternating equipment

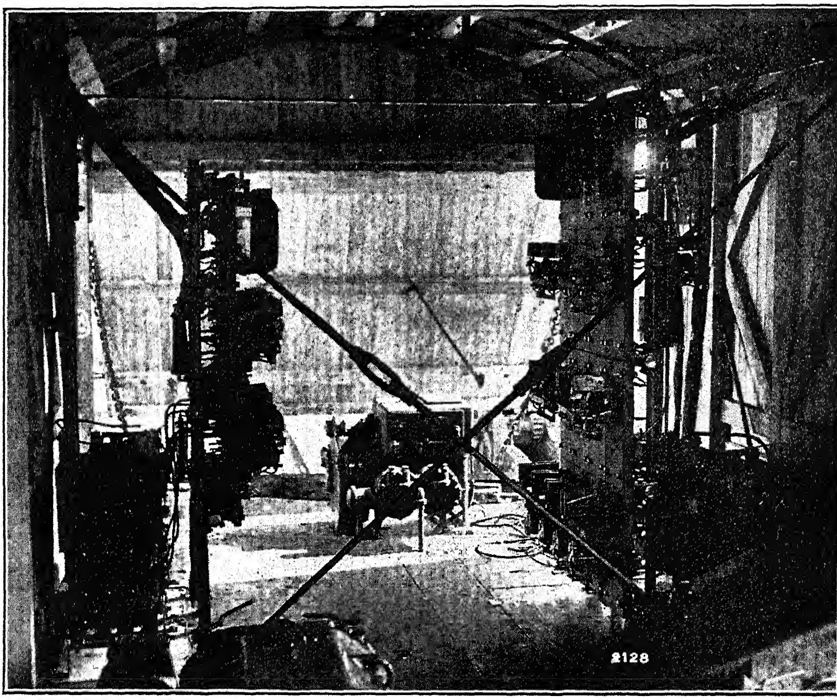

FIG. 5.—INTERIOR VIEW OF 65-TON ELECTRIC SHOVEL.

with transformers. In addition to this, any change in the frequency would mean a complete change in the equipment of an alternating-current shovel while it would mean only a change in the induction motor of the motor-generator set, with possibly a change in the generator fields, on a direct-current equipment.

DISCUSSION

WILLIAM KELLY, Vulcan, Mich.—This is certainly a very interesting paper, for the application of electricity to steam-shovel work is perhaps one of the most difficult of its applications. The full load comes on at once, is of very brief duration, and then the operation must come to rest.

The control must be positive, for if the moving parts go too far there is disaster. To control such a machine by electricity is exceedingly difficult. I would like to ask where electric shovels are in operation.

H. W. Rogers.—There are three four-motor direct-current shovels at the Empire Limestone Co.'s quarry, Sanborn, N. Y.; one four-motor alternating-current shovel operated by the Acton Rock Co., Los Angeles, Cal.; one three-motor alternating-current shovel owned by the United States Reclamation Service, near Fallon, Nev.; one three-motor alternating-current shovel at the Granite Quarries, Ltd., Vancouver, B. C., and several smaller friction electric shovels owned by the Ontario Power Co., the Los Angeles Aqueduct Co., the Milwaukee Electric Railway Co., and the Chautauqua Traction Co.

E. Gybbon Spilsbury, New York, N. Y.—I would like to ask whether the adoption of the motor-generator system, with heavy fly wheel, has been thought of in connection with this work. It is used in hoisting work in mines where the same conditions of stoppage and starting of heavy loads obtain. If a motor-generator set was put on the shovel, would not the intense peaks be more or less cut down?

H. W. Rogers.—The line peaks would undoubtedly be reduced by using a fly-wheel motor-generator set with Ward-Leonard control, but calculations which I have recently made on a 120-ton shovel equipped with a four-unit fly-wheel set show that the space occupied by the boiler and water tanks (approximately 15 by 9 ft.) is not sufficient, as the motor-generator set requires approximately 25 ft. In addition to this such an equipment would be too expensive to consider.

Thomas T. Read, New York, N. Y.—What are the chief advantages and drawbacks of the electric equipment as compared with steam-shovel work? One of the chief items of cost in shovel work in mining is lost time, and I was wondering what effect the electric equipment would have on that as compared with steam.

H. W. Rogers.—The chief advantages of the electric shovel are lower operating cost and reduction in lost time due to fewer repairs and breakdowns. The only disadvantage is the increased initial cost, which should not be considered apart from the operating expense. Whether a shovel is steam or electrically operated should not affect the spotting of cars and although the shovel may be idle during this process it is not using any power if it is electrically operated.

William Kelly.—There would be a saving in power, and there would also be a saving in the number of men used for operating the shovel. Are any of these shovels operated with one man?

H. W. Rogers.—So far as I know, all existing electric shovels require

two operators, although the service of the fireman, the watchman, the coal passer, a team for one-half day, and considerable oil and waste are eliminated. In addition to this there may be a further saving in power consumption, but this will depend entirely on the comparative cost of coal and power.

F. H. Armstrong, Vulcan, Mich.—I gather from your paper that you prefer the direct-current shovel. How would you advise a company equipped only with alternating current to handle this electric-shovel proposition?

H. W. Rogers.—That question is treated on the last two pages of the paper. I recommend the use of direct-current series motors with a motor generator, as the characteristics of the series motor very nearly approach those of the steam engine. I do not claim that it is impossible to operate a shovel with alternating-current motors, but that it requires motors of from 50 to 100 per cent. larger capacity than the direct current to accomplish the same results and with an increase in power consumption.

F. H. Armstrong.—I understood you to say there was not room on the shovel for a motor-generator set?

H. W. Rogers.—My answer to Mr. Spilbury's question was in reference to Ward-Leonard control with a four-unit, fly-wheel, motor-generator set, which cannot be mounted on a standard shovel on account of insufficient space.

F. H. Armstrong.—What I will have to say now really is not in discussion of the paper under consideration, because it is a somewhat different shovel, but in a sense it is an indirect discussion of it. I refer to an electric shovel which our company in Michigan is now constructing.

It has only one motor, and is a combination of an electric and a hydraulic operation. The motor drives a centrifugal pump, which pumps water to a pressure of 250 lb. into a pressure tank, above which is an air tank, to allow storage of power, and the water is carried to cylinders, one large plunger cylinder for the hoist, a smaller double-acting cylinder for the swing, with a rope from either end up to each side of the swing circle, and cylinders on the sides of the boom, double acting, for the thrust. We have only just built this shovel, and have not had it in the ore pile, and cannot say how it will work, but we have tried it out otherwise with fairly satisfactory results, as far as we can tell.

Walter Ferris,* So. Milwaukee, Wis. (communication to the Secretary†).—Mr. Rogers's article seems to the present writer to give a very incomplete idea of the actual present state of development of the

* Non-member. † Received May 1, 1914.

electric excavator. In brief, after classifying electric shovels into various types he proceeds with an argument to show the advantages of direct-current machinery over alternating-current machinery without calling attention to the large preponderance of alternating-current machines now in actual service. I have not the exact figures of the number of electric excavators put out by other concerns, but it seems a proper statement to make here that during the last two and one-half years the Bucyrus Co. alone has built 17 electric shovels and drag lines, all of which have been equipped with alternating-current motors with the exception of one small revolving shovel and one medium-sized drag line. The only reason for these exceptions is that alternating current was not available where these machines were to be used and we do not consider the advantage of alternating current over direct current sufficient to justify putting in a motor-generating set to obtain alternating current.

We do, however, believe that alternating-current equipment is distinctly superior to direct, not only because of the great advantage in simplicity of mechanism, but because the characteristics of wound rotor induction motors are better adapted to shovel service than are the characteristics of series motor. The ability of a series motor to run up to high speed under small loads has scarcely any application in shovel operation. The only part of a cycle where the load is small enough to take advantage of this point is just after the dipper is dropped into the pit, when the operator starts the hoisting motor. At this point the work to be done is to accelerate the rotor, take up slack chain, and move the dipper over any space which may intervene before it reaches the material to be dug. A little observation of shovels in actual operation will show that a good operator makes it a point not to have much slack chain to take up, and to lower the dipper into the pit close to the point where digging commences.

The digging stroke usually begins with quite an acute angle between the chain and the dipper handle, so that winding in sufficient chain to make 1 ft. of bail travel will move the dipper teeth forward 2 ft. or more in the direction of digging. For this reason it is not usually necessary to accelerate the hoisting motor very quickly. A good operator, either with electric motor or engine, starts his digging stroke quite gently, and there is no opportunity for the series motor to save time by running fast under light load at this part of the cycle. After the digging part of the cycle is completed, the full dipper frequently has to be raised several feet before it is high enough to dump into the car. In nine cases out of ten there is plenty of time to raise the dipper slowly before the swinging movement has brought it into dumping position. If this were not the case the series motor would not be able to raise the dipper fast any way, as the bail pull with a loaded dipper held out at dumping radius will require approximately the rated torque of the hoisting motor.

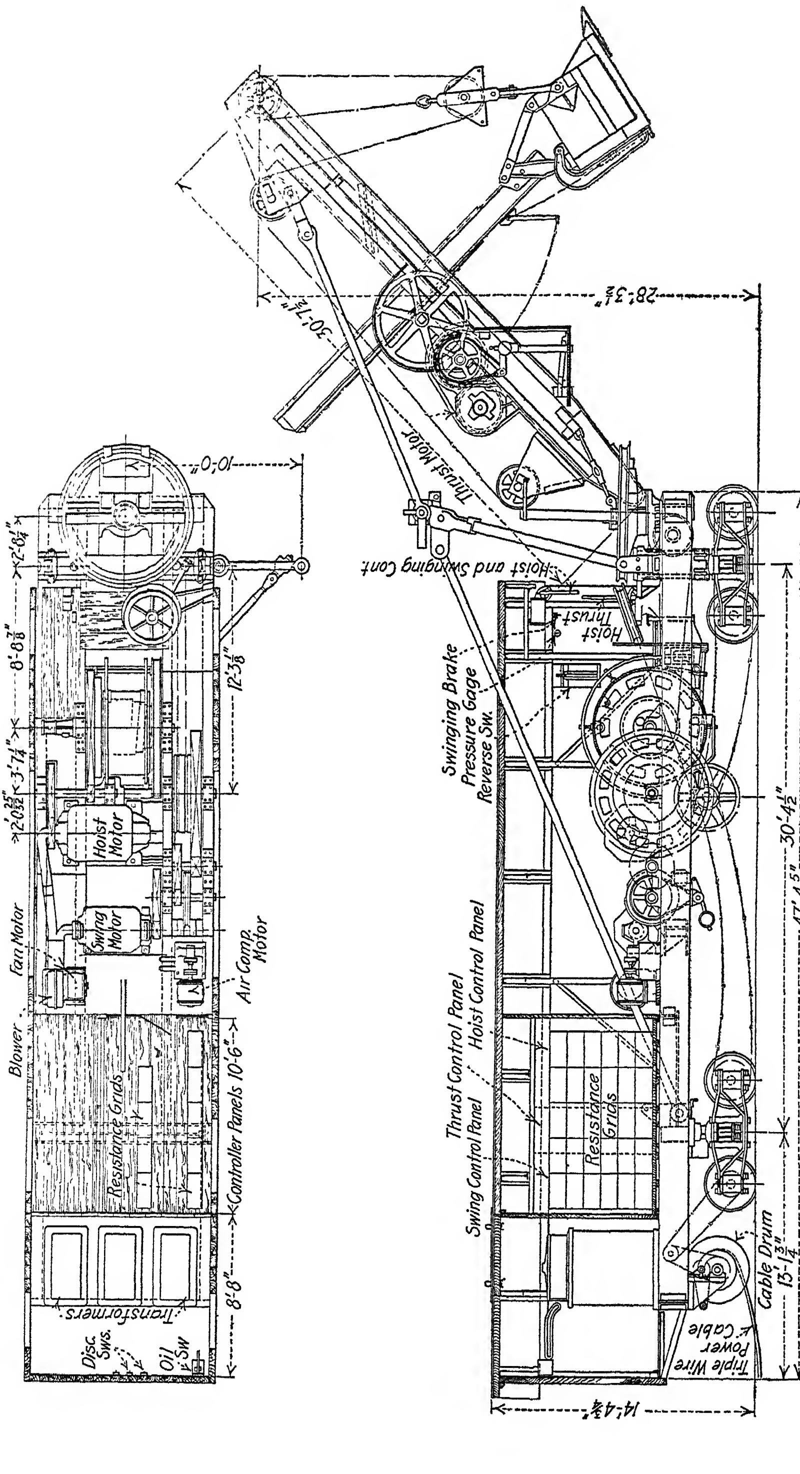

FIG. 8.—SHOVEL EQUIPPED WITH ALTERNATING-CURRENT MOTORS.

Let us now consider the action of the series motor during the heavy digging part of a stroke. At this time the motor is usually working considerably above its rated load and the speed will therefore be pulled down. A certain amount of speed reduction under heavy load is desirable. This amount should be enough to inform the operator about how hard the machine is pulling, but any further reduction in speed tends to reduce the output unnecessarily.

The wound rotor induction motor, provided with a proper amount of resistance in the rotor circuit, will very nearly approach the performance of the steam engine. It will start promptly, accelerating to full speed, if this should be desired, in less than 1 sec. After the dipper strikes the dirt it will pull through and load the dipper with a proper reduction of speed. After the dipper is full and is pulling out of the bank the motor will promptly accelerate to a speed very slightly above full-load speed, handling the dipper with all desirable promptness.

In some places it is advisable to place some permanent resistance in the rotor circuit, but the resistance is usually automatically cut in and out by solenoid switch control. The operator has a master controller which enables him to run the motor on any desired step of resistance, while the automatic solenoids will promptly cut in additional resistance should the current exceed a proper maximum. With this arrangement the author's statement that the maximum torque cannot be obtained on starting is quite incorrect. The rotor will either start or stall at maximum torque, and automatic jamming relays prevent the current from reaching the breakdown point.

While it is advisable to keep the rotor inertia small, we consider that neither any saving of power nor any saving of time is ever a gain such as to justify using two motors where only one is necessary. As in the case of steam shovels, small power economies do not usually govern in the matter of selection of proper equipment. In most of the electric installations now being made, coal is so expensive as to leave no doubt as to the desirability of electric equipment, and the cost of electric power is quite moderate, being frequently as low as ¾c. per kilowatt-hour. On the basis of actual results from shovels long in operation we find that the average current consumption per yard of material varies from 0.3 to 0.4 kw-hr. per yard excavated, possibly 0.75 kw-hr. for each cycle of a 2½-yard shovel. Taking the author's example in which he shows a saving of about 50 h.p. for 1 sec., due to small loads, I find this amount to be considerably less than 1 per cent. of the power used by the entire shovel during a single cycle.

When trifling savings of this kind are compared with the additional complications necessary to produce them the apparent economy usually disappears. In the present case the author shows an arrangement of main hoisting machinery involving two hoist motors with spur gear reduction

to two intermediate shafts, with two bevel or miter gear transmissions to a transverse pinion shaft. On this shaft is a spur pinion meshing with the hoisting-drum gear. For comparison with this we submit the arrangement of shovel machinery shown in Fig. 8, where the hoisting drum is driven by a single motor with two pairs of spur gears and one intermediate shaft as against the two motors, three pairs of spur gears, two pairs of bevel gears, and three intermediate shafts described by the author.

Pursuing the matter of simplicity, it appears that the alternating-current shovel involves three motors and three sets of slip rings as the only electrical rotating parts to be maintained. In many cases three stationary transformers are also used. As against this the author proposed for use with alternating supply a motor-generator set and four series motors with commutators. This makes a total of six revolving electrical machines, having five commutators and one set of slip rings. It is typical of shovel service that this electrical machinery will have to work in considerable grit and dust, which is particularly unhealthy for commutators. Slip rings are much less delicate and will stand a good deal of grinding down without giving trouble.

To justify such an excess of parts to be maintained we think a very strong case must be made out showing important advantages in favor of direct-current machines. The author claims a large excess in motor capacity which is required for alternating current. This is true to a certain extent, which we believe is much nearer 25 than 45 per cent. If the additional cost of maintenance, and especially the cost of delays which will undoubtedly be charged against commutator maintenance, could be figured, the writer believes that the amount would be largely in favor of the simpler alternating motors even at a higher cost.

As a matter of fact a large majority—probably at least three-fourths—of all of the large excavators (three-motor and four-motor machines) built during the past two years, have been equipped with alternating motors, and it is of record that the machines built by the Bucyrus Company have given uniform satisfaction and are all in successful operation at the present time.

H. W. Rogers (communication to the Secretary*).—It is not the purpose of my paper to deal with the present state of development of the electric shovel, except to show that it is a possibility, but rather to lend aid in settling the discussion as to whether direct-current series motors or alternating-current slip-ring motors should properly be used. The various types of electric shovels outlined will cover practically every one that is in operation at the present time, and the fact that several are equipped with alternating-current motors does not alter the situation.

* Received May 14, 1914.

When referring to shovels, I mean one particular type of excavator, which does not include the so-called drag-line excavator, which has a very much slower cycle and for which alternating-current motors are the best adapted when alternating current is available. Mr. Ferris mentions 17 excavators which he has equipped with alternating-current motors during the past two and one-half years, and in addition to these there have probably been a dozen more put out by other concerns.

There is no doubt but that the steam engine possesses ideal characteristics for shovel service and the motor that most nearly approaches these characteristics, whether it be direct or alternating current, is the most suitable motor to use. The series direct-current motor possesses these characteristics and requires a considerably smaller capacity, to do the same work, than the alternating-current motor, and although the motor may not be called upon to come to speed rapidly during every cycle, the increased inertia, due to the larger motor, will always call for an increased power.

Mr. Ferris, in referring to the saving gained by using two 75-h.p. motors instead of one 150-h.p. motor, states that this amounts to considerably less than 1 per cent., whereas it actually amounts to $1\frac{2}{3}$ per cent. of the power required during the complete cycle.

In comparing this drive with the one submitted by Mr. Ferris, from the efficiency standpoint, the gearing and shafting from one motor only should be considered, as the motors are operating in multiple. The comparison resolves itself into one extra pair of bevel gears and one intermediate shaft for the two-motor drive, which does not look as unfavorable as the comparison drawn.

So far as the operation is concerned, the series motor will give smaller variation in speed under heavy loads, on rheostatic control, and slightly greater variations in speed under light loads, without resistance in the circuit, than the induction motor, and will come to speed in a given time with considerably less power. It can be made to run at speeds above normal full-load speed while delivering full-load torque, whereas the induction motor cannot run above synchronous speed without additional equipment, which is too complicated and expensive to be considered for shovel service. As a matter of fact, the comparison made between direct- and alternating-current equipments in the paper is based on the series motor delivering full-load torque at the high speeds; otherwise the power consumption shown on this equipment would be about 8 per cent. less, and, taking into consideration the inertia, the power required by the alternating-current equipment would be slightly over 50 per cent. in excess of that required by the direct-current equipment. It would seem that such a saving is worthy of consideration.

While it need not necessarily be considered a disadvantage to the induction motor, it is a fact that the maximum torque is not obtainable at

standstill, but inasmuch as the maximum bail pull is not based on the maximum running torque this may be disregarded. As far as simplicity is concerned, the direct-current control requires fewer contactors, is less complicated, and less expensive than the alternating-current control and the motors recommended are of the mill type, totally inclosed construction, which eliminates any commutator trouble due to grit or dust.

The motor of the motor-generator set would not be of the slip-ring type and consequently would give no trouble due to collector rings. There is no doubt whatever about the possibility of operating a shovel with alternating-current motors, but when taking all things into consideration it is more advantageous to use the direct-current equipment, even though it makes the use of a motor-generator set necessary.

*

The Safety of Underground Electrical Installations

BY C. M. MEANS, PITTSBURG, PA.

(New York Meeting, February, 1914)

CONSIDERING the hazard involved in mining operations, statistics show that a very small percentage of accidents is chargeable to electricity. These accidents do represent quite a large percentage of those that are preventable and they are the direct result of the introduction, for purely economical reasons, of a dangerous element. The introduction of electricity in mines should decrease the hazard, and in no case should electricity be applied to the mechanical operation of equipment if by so doing the dangers incidental to mining are increased.

The greater number of accidents are the result of persons coming in contact with exposed conductors at potentials varying from 250 to 500 volts direct current. The use of alternating current at higher potentials than these is quite common in large mines, but it is very rare that an accident happens from this source. This is explained by the fact that where these high voltages are warranted, proper precautions are taken, and the installations are directed by those who fully appreciate the dangers incidental to the work. Direct current is in much more general use than alternating current because of its adaptability to haulage locomotives and the low cost of installation in small operations. We are, however, coming to a more extended application of alternating current for the operation of mechanical devices used in connection with mining.

Our underground direct-current wiring system is an evolution from the surface trolley and feeder systems. This is probably due to the fact that our earlier successful applications were electric locomotives, which required the use of a trolley wire. The trolley current has been almost banished from industrial establishments on the surface because of the hazard involved, yet we use it indiscriminately underground, where the dangers from accidental contact or fire are infinitely greater. This does not mean that the underground trolley systems should be eliminated, but it does imply the proper safeguarding of such equipment as is necessarily a part of the trolley systems.

It is a fact that the men now employed in the installation and maintenance of mining equipment may be in many cases incompetent or not thoroughly familiar with the work, but they are the men who must do the work and, in order to do it properly, it is necessary that they be educated

and guided in their task. Men who have been trained in industrial plants on the surface do not care to take up mining work, and the men to do underground electrical work must be recruited from men actually working in the mines. These men have no training except that gained from association with men engaged in the work. The result is, they do their work in such a manner as seems to them the most expedient with the results to be attained, and not in keeping with any clearly defined method or studied system.

For all electrical work on the surface we have the rules of the Underwriters' Association. Electricians and wiremen familiarize themselves with all requirements of the Underwriters, and the result is that their work is done in a thorough and safe manner. A complete set of electrical rules similar to those of the Underwriters' Association, but made applicable to underground work, would go a long way toward solving the problem, if they were made suitable for, and received, general application.

These rules would naturally be evolved from all data available and an investigation of all electrical accidents over a period of time; and a complete analysis should be made of causes, as well as methods to prevent a recurrence in the future. We have available the rules contained in the bituminous mine law of Pennsylvania and other States, rules of the Underwriters' Association, and rules of certain mining corporations and municipalities, that could be used for a basis. Any set of rules, no matter how carefully compiled, will naturally meet with a considerable amount of opposition and criticism, and a large part of the criticism will be warranted. This very feature will result in devising a set of rules that will meet the situation in its entirety, and make it possible to almost eliminate this class of accidents.

The problem of working out such a set of rules is a very formidable one, but no more difficult of solution than that which the Underwriters' Association has already solved or is successfully solving. It is fully apparent that additions or changes must be made from time to time to keep pace with an industry that is continually being developed and expanded.

The electrical rules contained in the bituminous mine law of Pennsylvania have been in effect something over two years, but last year represented the first opportunity we have had to judge the operation and effect on fatalities resulting from the use of electricity. While the exact records are not available, it is safe to say there will be a material decrease in the number of fatalities from the use of electricity in this district, and this in face of the fact of a very material increase in the use of electrically driven devices used in the production and transportation of coal.

These rules represent a first step in the standardization of electrical equipment and wiring as applied to underground workings, and the results stated are conclusive proof of what can be done along this line. These rules have resulted in the education of the men who do the work, and

they now know, in a general way, what they are required to do. Prior to the enactment of this law, the use of electricity in mines was tolerated but not authorized, and not subjected to any rules or regulations. It is only natural to suppose that this resulted in installations of all kinds. Some installations represented an unnecessary expense in doing everything possible to meet every restriction that might later be placed on the work, but a large number of the plants were put in simply to do the work, with very little regard to the safety of the employees. This is all changed now, and each operator knows what is required, and, wherever possible, meets all of the provisions contained in these rules.

These rules met with more or less opposition when first incorporated in the mining law, but they now meet with the favor of all progressive mining companies and have been of material value to all concerned.

Instead of restricting the use of electricity, these rules have caused a very material increase in this method of transmitting power to operate the different mechanical devices used in the production of coal, and are of material value to the coal industry in this region, as well as to electrical and kindred industries.

When the Underwriters' Association introduced rules governing electrical work, inspectors were employed to see that the work was done in keeping with the standard suggested by their code. Formerly these inspections covered all work done where insurance was carried, but as the workmen became more skilled the inspections were less comprehensive, and under certain conditions were omitted entirely.

For a period of time it will be necessary to employ a certain number of electrical inspectors for underground work to see that the rules are complied with. An inspector would be of little value unless he had a definite set of rules on which to base his recommendations. His duty will be to act largely in an advisory capacity and to interpret the rules laid down The mining departments of the different States employ a certain number of mine inspectors, who can take care of the electrical work after they get entirely familiar with the rules and application, except where new schemes or unusual installations are involved. It may require some little time for these inspectors to become sufficiently familiar with electrical equipment and its operation, but a knowledge of this phase of the situation will be just as essential and as readily acquired as that of ventilation.

In the bituminous fields of Pennsylvania the mine inspectors paid very little attention to the electrical equipment so long as the use of electricity was simply tolerated, but just as soon as its use was authorized, and rules formulated covering the work, they familiarized themselves with the rules and their application, and in the average installation they are able to judge intelligently as to the safety of the equipment.

It is not within the province of this papeı to suggest who should work out a proper set of rules or how they should be applied. The increased

safety that would be secured would fully warrant the co-operation of our government, both National and State. Electrical manufacturing companies should be very much interested because of the commercial advantages gained by reducing the hazard, thereby popularizing the use of electrically operated devices. The mining companies should also be interested because of the reduced hazard to employees and property that would naturally follow. A more extended application of electricity would be warranted with reduction in costs of operation. All safety organizations, as well as engineering societies, would be interested.

Taken in its entirety, considering the increased safety that would naturally follow, the commercial advantages to be gained, and the large number of interests involved, the expenditure of the necessary time, labor and money is fully warranted in the formation of a proper set of rules covering this work.

Application of Electricity to Mines and Mills of Witherbee, Sherman & Co., Inc., Mineville, N. Y.

BY S. LE FEVRE, MINEVILLE, N. Y.

(New York Meeting, February, 1914)

THE application of electricity to the mining and beneficiation of the magnetic iron ores of the Mineville, N. Y., district, on Lake Champlain, has resulted in economies and enhanced quality of product, without which only a comparatively small quantity of the present output could be marketed. The output of the Witherbee, Sherman & Co. mines is about 700,000 tons per annum, and of this about four-fifths is treated by magnetic separation to increase the iron content and reduce the phosphorus.

The use of electricity for the magnetic separation of the ore from the gangue is therefore of primary importance, and makes possible the application of electric power for mining and preparing the ore for concentration. The fact which speaks loudest in favor of the application of electricity is this: It is possible for about 25c. per ton of shipping ore to furnish all the power required to put the ore on cars. This includes mining a hard ore underground, from a depth of 900 ft., hoisting to surface, crushing to $\frac{1}{4}$ or $\frac{1}{8}$ in. in size, and separating from the gangue. This also includes lights about the works, and all miscellaneous power, such as about the shops.

The first plant for the generation of electric power for use at Mineville was completed in 1903, and was one of the first for the application of electricity to mining iron ore. This was a Nordberg compound condensing steam engine, direct connected to a 750-kw. alternating-current generator, 3,300 volts, 3 phase, 25 cycles. All the plants added later use the same current but with higher voltage. The map, Fig. 1, shows the power plants and the transmission system; Figs. 2 and 3 are views of the shaft houses and the mills.

The power from the first plant was distributed to Mills 1 and 2, one 2,500 cu. ft. compressor, and to the Harmony hoist, which was driven by a 300-h.p. motor operating four 10-ft. drums. Our experience with the hoist covers largely the development of electric hoisting from 1903 to date, and in some cases improvements were worked out to satisfy our needs. The motor is still operating as installed, but the control apparatus has been radically changed several times. When installed, the iron re-

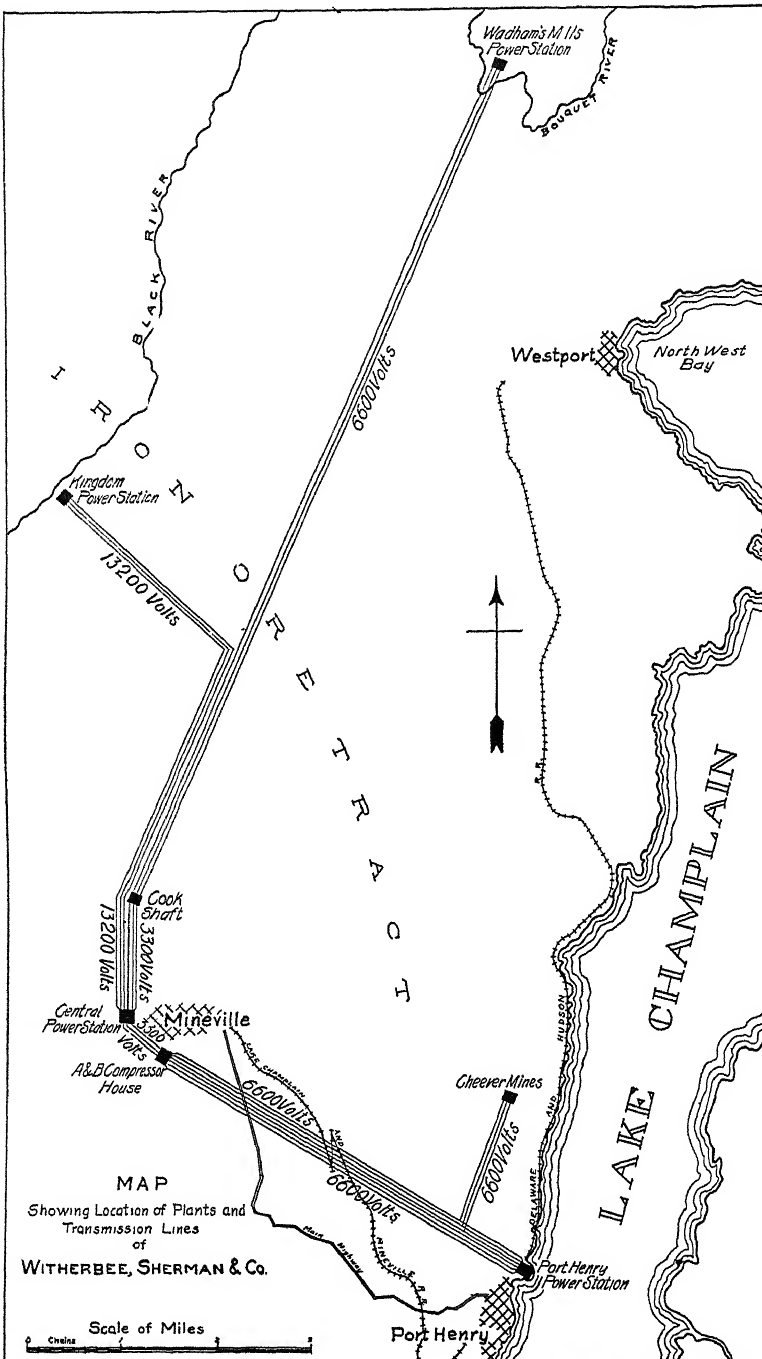

FIG. 1.—MAP SHOWING LOCATION OF PLANTS AND TRANSMISSION LINES OF WITHERBEE, SHERMAN & CO.

sistance grids were light, and they would vibrate when the rush of current entered, sufficiently to touch and short circuit, and burn out; it was a

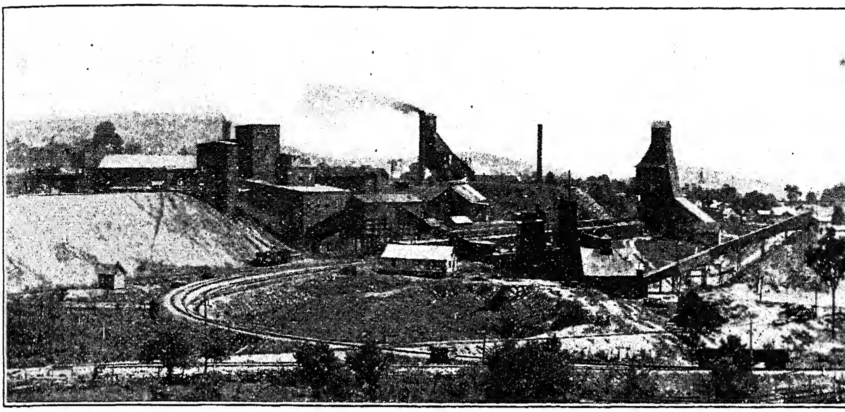

Fig. 2.—Joker, Bonanza and Clonan Shaft Houses, Mills Nos. 1 and 2, and No. 1 Power Station.

regular thing to replace those burnt out, between shifts. We then increased the weight about four times and got very good results. Still later we installed a water rheostat, which has been in operation about two

Fig. 3.—View of No. 4 Mill.

years and has cost practically nothing in repairs, besides being very much smoother in operation and acceleration.

The heavy duty on the control of this hoist is due to the four drums attached to one motor. When one car is hoisted slowly for men, and the other cars have ore in them, the motor gets full load at slow speed and a very heavy current must be carried by the resistance in the rotor circuit.

As the depth and output increased the 300-h.p. motor was overloaded, and the delays in hoisting due to handling men were considerable. On that account a new double-drum hoist is now being installed, and two drums of the old hoist will be discarded.

The hoist serving the Joker shaft (Fig. 4) has double drums, 10 ft. in diameter, 6-ft. face, geared to a 500-h.p. motor, and hoists 3 tons

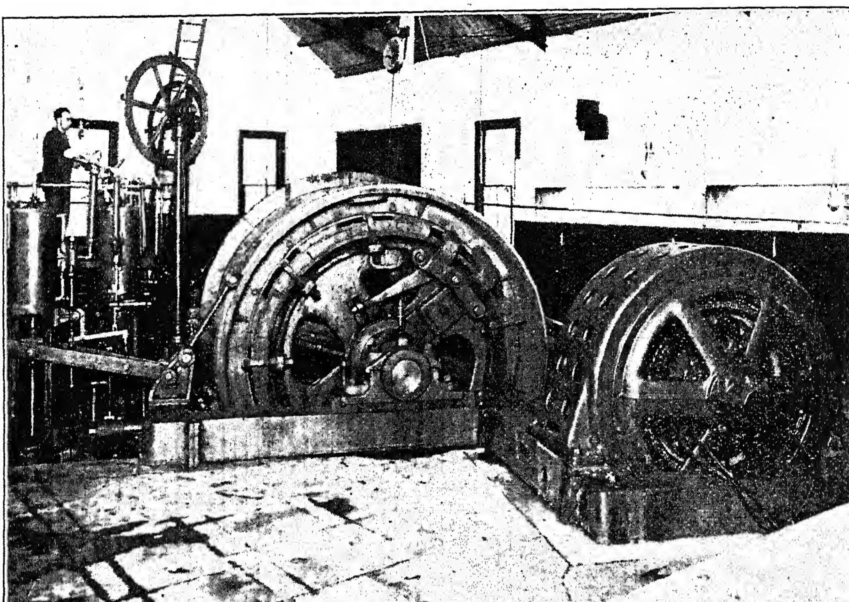

Fig. 4.—Double-Drum Hoist for Joker Shaft in No. 1 Power Station.

of ore in each skip at 900 ft. per minute, the two skips being in balance. It takes 1 kw. of power to hoist 1 ton of ore 375 ft. This hoist will deliver forty 3-ton skips per hour from a depth of 900 ft. This allows 3 min. for a round trip of each car.

The ore includes lumps up to 2 or 3 ft. in diameter mixed with fines. This is drawn out of a pocket, through a door 4 ft. square, opened and closed by a 12-in. diameter air lift, into a measuring chute 12 ft. long on an angle of 45°, at the bottom of which is a lip chute raised to hold back the skip load. As soon as the car lands, the lip chute is dropped, the car loaded, and the signal given to hoist in from 15 to 30 sec. The

measuring chute is then filled while the skip goes up and back. A little skill in following the descending car with the loading lip chute often makes the signal to hoist reach the engine room at the same instant with the roar made by the dumping of the ore from the other car in the shaft house. Heavy cast-iron grids are used for resistance on this hoist and have given no trouble. Double-pole contactors are used, which are operated by a master controller on the operating platform (Fig. 5). The hoisting costs about 2c. a ton for power. With the steam hoist the cost was 7c. per ton, a saving of 5c. per ton in favor of electric hoisting.

We are now installing four new hoists underground. The depth of the workings and the shape of the ore bodies make it advisable to

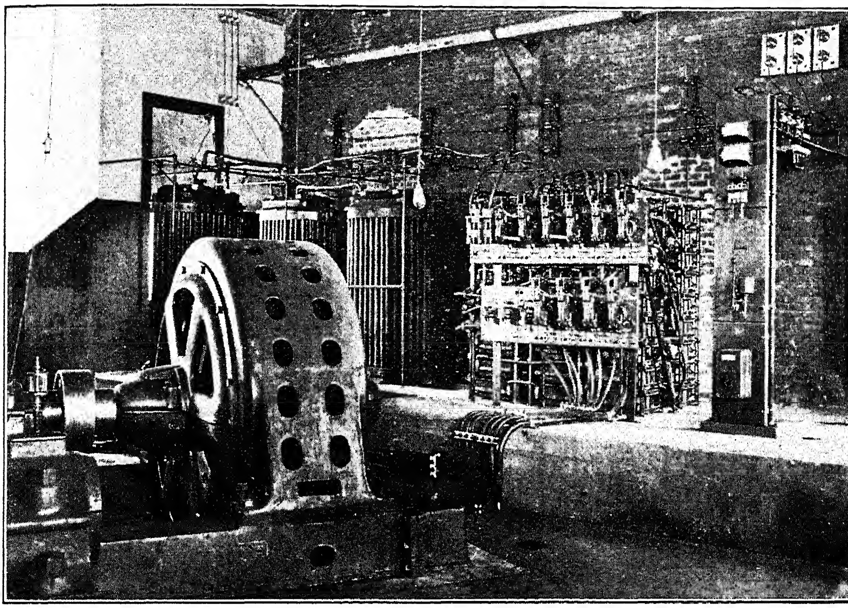

Fig. 5.—Transformers and Contact of Panel for Joker Hoist Motor.

divide the hoist. The underground hoists operate on slopes from 25° to 40° from horizontal, and dump into pockets, from which the ore is reloaded into skips and hoisted up shafts which are vertical or nearly so.

These new hoists, shown in Fig. 6, a shop view, have double drums 7 ft. in diameter, 3-ft. face, with a single reduction of Wuest herringbone gears to the shaft of a 300-h.p. motor. This is arranged so that if desired to operate to capacity without working in balance, another 300-h.p. motor can be added on the opposite side. The hoists were all sectionalized to go down a 4 by 4 ft. compartment in shaft.

These hoists will be equipped with a new type of liquid rheostat

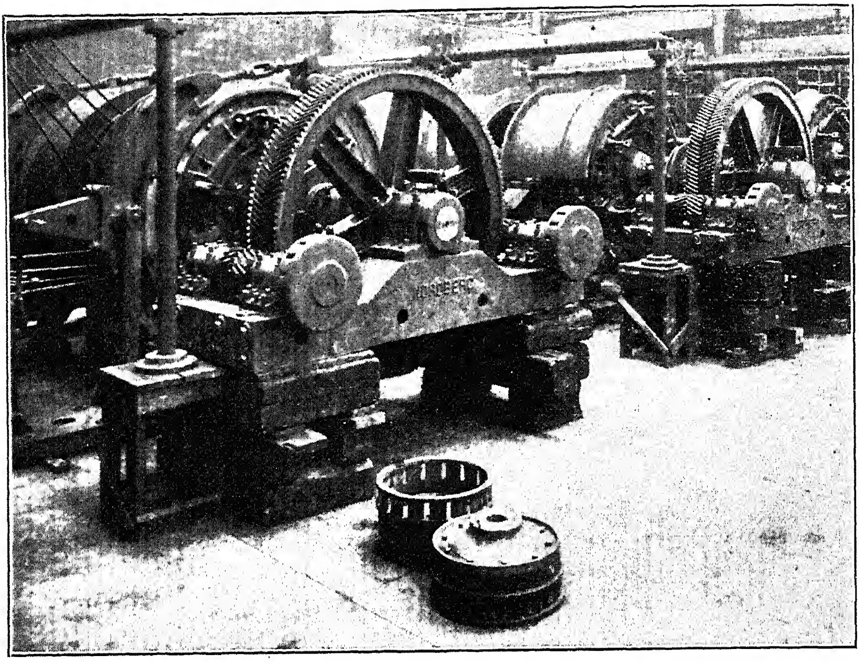

FIG. 6—SHOP VIEW OF HOISTS TO BE INSTALLED UNDERGROUND AT MINEVILLE.

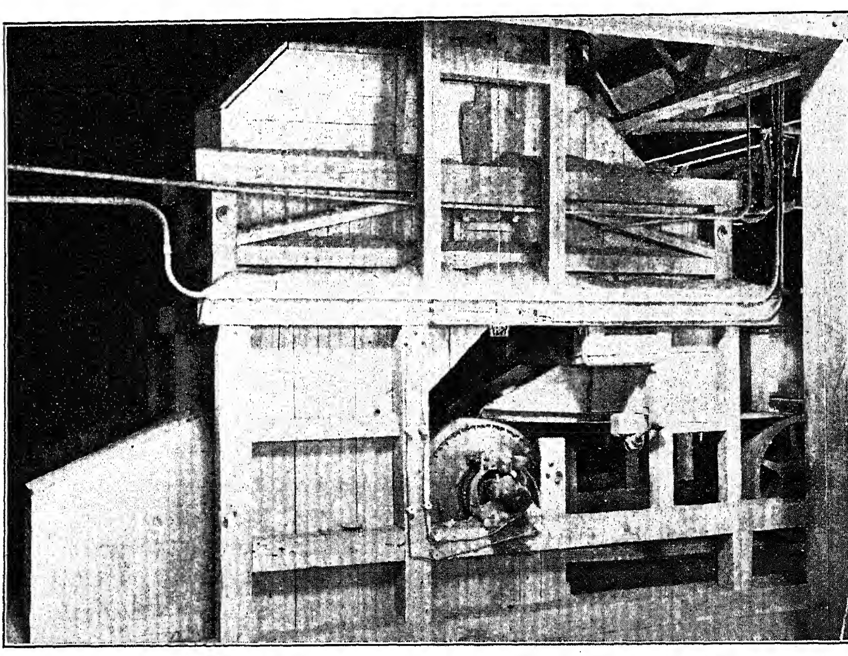

FIG. 7.—DRUM TYPE OF MAGNETIC ORE SEPARATOR IN USE AT MINEVILLE.

which has two sets of electrodes, one set of pipes which are spaced far apart and are used for starting, and another set of plates which are spaced close to give a very small slip when full speed is desired. This eliminates the danger of the rheostat arcing over if the motor is suddenly reversed, and also gives a much wider range of speed than the ordinary type of rheostat.

The separators used are the Ball-Norton type as developed by S. Norton at Mineville, N. Y., and are simple in construction and operation; they handle large quantities. Three types are in use: the drum machine (Fig. 7), the belt machine (Fig. 8), and the pulley type, or rock picker. The drum machine is used on material from 2 in. to ½ in.,

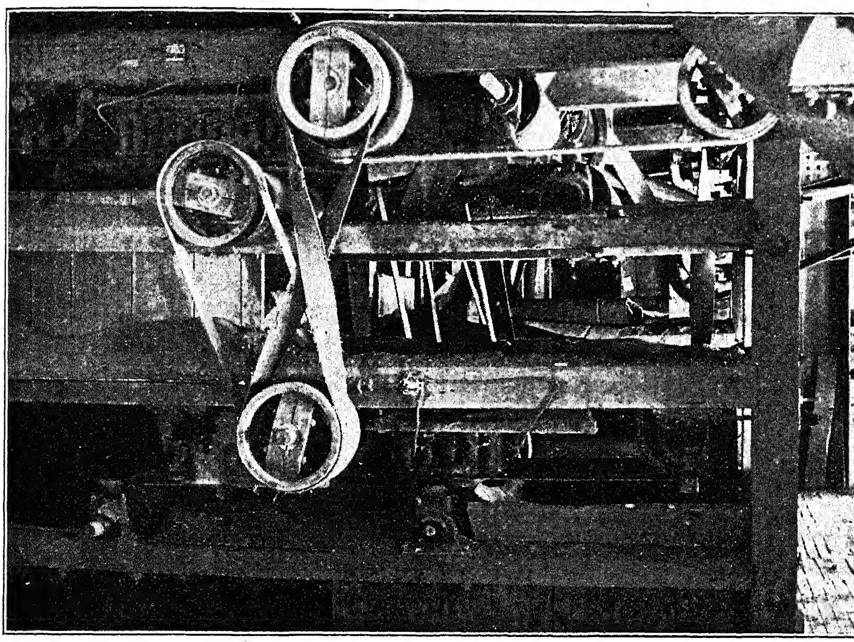

Fig. 8.—Belt Type of Ore Separator in Use at Mineville.

although it will work on finer sizes, but the belt machine is preferred on ¼ in. or finer, as it costs less and is more open for examination and repairs.

The drum machines are usually 30 in. in diameter, 15-in. face, with brass shell revolving about the face of the magnets. These are suspended in a fixed position inside the drum, taking up about half of the periphery.

The belt machine has the magnets suspended in a horizontal position over the take-off belt, and under the return of same. The feed belt runs below the take-off belt, and when the ore comes under the first

magnet, which is only a few inches from the end of the feed belt, it is lifted up to the under side of the take-off belt and carried along until it reaches the last magnet, where it drops over a division board into the concentrates. The tailings drop into the space between the end of the feed belt and the division board.

The magnets are so connected in the wiring as to be of alternating polarity. One end of a particle of ore is attracted to a magnet, and as the belt carries it forward the other end turns to the following magnet, thus turning the stream of ore over and over, and leaving the gangue free to drop, instead of being carried along enmeshed in the ore.

The pulley type machine, or rock picker, is used in the head end of a conveyor, and has a full circle of magnets, which revolve with the pulley. This is used with a heavy current, and holds to its face anything with ore in it. The pure rock flies off over a division board set ahead of the pulley.

In making the concentrates from the Mineville ores, that from the Old Bed mine is crushed to $\frac{1}{4}$ in., but this is because the chief object is to reduce the phosphorus. For the Harmony and New Bed concentrates, the most economical practice is to pass the crude ore, after crushing to a maximum of 2 in., over a drum machine, which picks out the rich ore, as heads or concentrates, leaving the balance as middlings, which are passed over a pulley machine and by this divided into tailings and middlings. The middlings from the pulley machine are then passed through rolls, and the same process is repeated. When the material is reduced to $\frac{1}{4}$ in., belt machines are substituted for the drum machines.

The use of the pulley machines reduces materially the amount of work the rolls have to do, and also the bulk of material to be treated by the final machines. This treatment also recovers the ore in the coarsest possible state, consistent with maintaining the desired percentage of iron.

We make occasional car loads of concentrates, used for magnetite arc lights, guaranteed to contain 70 per cent. metallic iron, and have reached 71.2 per cent., leaving only 1.2 per cent. of total impurities, as pure magnetite carries 72.4 per cent. iron.

Direct current is used for the magnets at about 125 volts, and the amount of current on the individual machines runs from 3 to 7 amperes on the machines making heads, and up to 25 amperes on the pulley machines. The adjustments on individual ores to get the desired results are variations of the current, air gap, and belt speeds.

A table is appended showing the average results obtained for the year 1913 in the various mills. The recovery runs from 90 to 98 per cent. of iron in the crude, as concentrates containing between 62.5 and 66 per cent. metallic iron.

Slip-ring induction motors are used principally, and with reversible

controller, which is very desirable when putting on belts, or when crusher or rolls block. In this case a slight reverse releases the material.

We have been using 220-volt direct current for the mine lighting, and the electric haulage used current from the same circuit. In the near future a transformer will be installed to reduce the alternating current to 110 volts and this will be used for lights, which will then be taken off the trolley circuit. Clusters of incandescent lights are used in chambers instead of arc lights.

The distribution of current about Mineville is at 3,300 volts, with transformers from 3,300 to 440 near each motor or group of motors.

All of the electrical apparatus of the present equipment is of General Electric manufacture, and the plant was described in the *General Electric Review* of February, 1912, to which we are indebted for some of the illustrations used herewith. We wish to acknowledge also valuable assistance received from H. F. Pigg, Mechanical and Electrical Engineer for Witherbee, Sherman & Co.

The tables appended give the generating units, having a total capacity of 4,975 kw., and a recapitulation of the distribution of the power for the year 1913, also lists of the motors installed.

The generator capacity is about 70 per cent. of that of the motors installed, and the power used is about 60 per cent. of the motor capacity. The average operating cost of power was \$0.0091 per kilowatt-hour, and with depreciation of plants added \$0.0105.

Compressed air is the principal item of power cost and took 10.5 kw-hr. per ton of crude ore mined, or $73\frac{1}{2}$ per cent. for compressed air out of a total for mining of 14.3 kw-hr. The milling took 4.1 kw-hr. and the total power for all purposes was 18.7 kw-hr. per ton of crude ore produced.

The distinct advantage which magnetic ore has over the other marketable varieties lies in the ease and certainty with which it can be separated from the gangue, after the particles of ore are crushed free from the rock. In this respect the Lake Champlain ores have a great advantage on account of coarse crystallization, so that crushing to $\frac{1}{4}$ or $\frac{1}{8}$ in. permits a recovery of from 90 to 98 per cent. of the iron in the crude in the form of a uniformly high-grade concentrate with a small percentage of objectionable fines. The quality of the concentrate can be made to stay practically constant at whatever point may be fixed as the best economic limit, without regard to the iron content of the crude ore, whether it be 25 or 55 per cent. iron, which is about the range of the ores treated.

This advantage ought to increase very materially the amount of magnetic ore used, as the demand for increased ore tonnage continues to grow. The quantity of iron ore used doubles every ten years. To provide this, even if the amount of imported ore grows largely, prepara-

tion must still be made at a rapid rate for new mines and increased outputs of present mines.

Concentration Results, Average, 1913

	Crude Fe, Per Cent.	Tails Fe, Per Cent.	Concentrates Fe, Per Cent.	Concentrates Phos., Per Cent.	Recovery, Per Cent.	Tons Crude	Tons Concts.	Ratio
Old Bed concentrates.								
Mill No. 1..........	54.38	5.30	63.75	0.74	98.42	87,157	73,190	1.191
Mill No. 2..........	55.21	7.88	65.15	0.67	97.53	170,161	140,576	1.21
Cobbing plant..... .	53.41	6.98	60 71	1.26				
New Bed concentrates.								
Mill No. 4	34.16	6 25	65.04	0.027	90.41	192,137	91,230	2.106
Harmony concentrates.								
Mill No. 3..........	47.79	7.34	62 67	0.087	95.93	223,787	163,854	1.366

Equipment of Power Plants

Power Plant: Location	Power Plant: Drive	Generators: Kilowatts	Generators: Volts	Amount Produced, 1913: Kilowatt-hours
Port Henry..............	Turbine.............	800	6,600	7,453,700
	Turbine........... ..	1,500	6,600	
Central.................	Engine.............	750	3,300	4,306,800
	Turbine.......	750	3,300	
Total steam...........	....	3,800		
Wadhams...............	Water wheel.........	375	6,600	788,300
Kingdom................	Water wheel.........	800	13,200	1,870,700
Total..................	....	4,975	....	14,419,500

Recapitulation—Distribution, 1913

	H.P. of Motors Installed	Kilowatt-hours		Per cent. of Full-Load Capacity Used
		Total Used	Per Ton Crude Ore	
Compressors	2,100	7,273,365	10.5	93
Hoists	2,200	1,664,956	2.5	20
Hoists, new	1,200			
Pumps	131	287,554	0.4	60
Haulage	....	212,083	0.4	54
Mine lighting	275	333,826	0.5	
Total mining	5,906	9,771,784	14.3	55
Mills	2,094	2,756,408	4.1	76
Carpenter shop and saw mill	95	89,019	0.13	
Sherman mine development	....	98,084	0.14	
Total power used	8,095	12,715,295	18.7	60
Commercial power	1,150 50	1,704,205		
	9,295	14,419,500		

Compressors—Motor Distribution

Location	Horse Power	Volts	Service
A and B power house	400	3,300	2,500 cu. ft. compressor, synchronous motor.
	400	3,300	2,500 cu. ft. compressor, synchronous motor.
	400	3,300	2,500 cu. ft. compressor, synchronous motor.
	200	440	1,250 cu. ft. compressor.
	200	440	1,250 cu. ft. compressor.
No. 1 power house	200	440	1,250 cu. ft. compressor.
Smith mine	75	440	600 cu. ft. compressor.
	75	440	600 cu. ft. compressor.
Sherman mine	150	440	600 cu. ft. compressor.
Total	2,100		

NOTE.—Synchronous motors are operated at 80 per cent. power factor leading, which brings up the power factor at the distributing points in Mineville to about 93 to 94 per cent.

Hoists—Motor Distribution

Location	Horse Power	Volts	Service
No. 1 power house...	500	440	Double drum—Joker shaft.
	300	3,300	Double drum—Bonanza shaft.
A and B power house.	300	440	Double drum—B shaft.
	300	3,300	Double drum—A shaft.
Smith mine.........	100	440	Double drum.
Sherman mine.......	52	440	Single drum.
Underground			
Barton Hill.........	52	440	Single drum—Intermediate sink.
	52	440	Single drum—South pit.
	52	440	Single drum—South pit.
	35	440	Single drum—Orchard.
	22	440	Single drum—South pit raise.
	22	440	Single drum—South pit raise.
	22	440	Single drum—North pit raise.
Harmony...........	52	440	Single drum—E. side, A sink.
	52	440	Single drum—W. side, A sink.
	52	440	Single drum—B sink.
	22	440	Single drum—A pocket.
	300	440	Double drum—A shaft circle.
	52	440	Man hoist—A shaft circle.
Old Bed............	35	440	Single drum—Miller pit sink.
	22	440	Single drum—Miller pit raise.
	52	440	Single drum—Slope No. 1—To be replaced.
	52	440	Single drum—Slope No. 2—To be replaced.
	52	440	Single drum—Slope No. 3—To be replaced.
	300	440	Double drum—Slope No. 1—Partly installed.
	300	440	Double drum—Slope No. 2—Partly installed.
	300	440	Double drum—Slope No. 3—Partly installed.
Total.............	3,452		

Pumps—Motor Distribution—all 440 Volts

Location	H.P.	Service
Smith mine..........	30	
	5	Bottom.
B shaft.............	30	Circle.
	15	Bottom.
A shaft.............	12	Circle.
	5	Bottom.
Old Bed.............	5	No. 6.
	3	No. 4.
Barton Hill..........	3	
	3	
Surface.............	15	B shaft water supply.
	5	B shaft water supply.
Total.............	131	

Power Houses—Motors

Location	H.P.	Volts	Service
Port Henry.........	50	440	35-kw. motor-generator exciter.
	6	440	Ventilating fan for 800-kw. turbine.
Central...	50	3,300	Motor-generator exciter.
	5	440	Centrifugal pump for condenser
	10	440	Ash conveyor and elevator.
No. 1 power house...	110	3,300	75-kw. motor generator for direct current —220 volts.
	50	440	35-kw. motor generator for direct current —220 volts. (These two for lights and haulage.)
	110	3,300	Two 37½-kw. D.-C. generators, 125 volts (Spare).
Direct-current motors	22	....	Hoist in Old Bed, Overland.
	22	....	Hoist in Old Bed, Overland.
	5	....	Pump at Bonanza circle.
	50	....	Five locomotives, two 5-h.p. motors each, trolley haulage.
	9	....	Two locomotives, one 4½-h.p. motor each, tailings cars.
	20	....	Three-car tipple, Joker shaft.

Mills—Motor Distribution—All 440 Volts A. C.

	H.P.	
Mill No. 1........	75	Group drive.
	75	Group drive.
	75	Group drive.
	60	Group drive.
	35	Crusher—Joke shaft house.
	75	Cobbing plant.
Total............	395	
Mill No. 2..........	100	Group drive
	100	Group drive.
	100	Group drive.
	30	Hoist for hauling cars.
	15	Conveyor to bin.
	50	35-kw. motor generator, 125 volts, magnet current, and mill lights.
Total	395	
Mill No. 3...... ..	200	Section ½ mill.
	200	Section ½ mill.
	50	35-kw. motor generator, 125 volts.
	35	Crusher and conveyor, B shaft.
	20	Conveyor to mill.
	35	Crusher, A shaft.
	20	Conveyor to mill.
	5	Elevator.
Total...	565	
Mill No. 4.	150	Group drive.
	150	Group drive.
	150	Group drive.
	150	Group drive.
	20	Tailings conveyor.
	2	Repair shop.
	2	Fan for drier.
	35	Coal-car hoist.
	5	Elevator.
	75	50-kw. motor-generator set, 125 volts, for D.C., for separators and lights.
Total............	739	

Miscellaneous Motors

	H.P.	Volts	
Saw mill............	60	440	Saws.
	35	440	Carpenter shop and planer
Smith mine.........	6	440	Fan for drill forge.
Sherman mine.......	6	440	Fan for drill forge.
Fertilizer plant.....	60	440	Tube mill and conveyors, under construction.
Commercial power:			
Mineville Light H. & P. Co.			
Street lights.			
Residence lights.			
Cheever Iron Ore Co.	400	6,600	Compressor.
	200	6,600	Compressor, synchronous motor.
	225	440	Hoist.
	75	440	Hoist.
	37½	440	Hoist.
	37½	440	Hoist.
	37½	440	Hoist.
	15	440	Repair shop.
	5	440	Repair shop.
	75	440	Mill.
	50	440	Mill.
	25	440	Mill.
	16	440	Pumps.
	10	440	Haulage locomotive.
Total............	1,208½		

Use of Electricity at the Penn and Republic Iron Mines, Michigan*

BY WILLIAM KELLY AND F. H. ARMSTRONG, VULCAN, MICH.

(New York Meeting, February, 1914)

The object of this paper is to describe the electric equipment at the iron-ore mines of Penn Iron Mining Co., Vulcan, Mich. and of Republic Iron Co., Republic, Mich.; to give the results of tests; and to discuss the methods in use from an operating as well as from an efficiency standpoint.

Electricity was introduced at the Penn mines for pumping, hoisting, and compressing air in the spring of 1907, upon the completion of a hydro-electric plant built by that company on the Menominee river about 4 miles from the mines. This plant was described in a paper[1] presented before the Lake Superior Mining Institute. A paper[2] presented at a meeting of the same Institute describes some of the operating features, and the safety devices of the electric hoist at the Curry shaft were briefly described in the *Proceedings* of the First Co-operative Safety Congress held under the auspices of the Association of Iron and Steel Electrical Engineers at Milwaukee, Wis., Sept. 30 to Oct. 5, 1912.

Generating Power Plants

After the success of electrical operation was assured, a second set of water wheels and generator was installed at the falls, for which provision had been made in the original design and in the construction of the foundations, and later three additional wires were added to the main transmission line, doubling its capacity and reducing the line loss.

The general conditions of this installation are particularly favorable for hydro-electric operation. In the neighborhood of three-fourths of the power used is for mine pumping, which in the main is regular and continuous. For air compressing, power is used for about 18 hr. a day for five days, and 9 hr. for one day in the week, though occasionally when shaft sinking is going on a very small amount of compressed air may be

* To be presented also, by mutual agreement, at the meeting of the Lake Superior Mining Institute, August, 1914.

[1] T. W. Orbison and F. H. Armstrong, *Proceedings of the Lake Superior Mining Institute*, vol. xiii, pp. 153 to 181 (1908).

[2] Frank H. Armstrong, *idem*, vol. xvi, pp. 244 to 250 (1911).

required continuously. Hoisting and surface tramming, which are intermittent, require only about 6 per cent. of the power used. The pond above the falls covers an area of about 450 acres and the head is 25 ft. There is, therefore, an ample quantity of water to take care of the ordinary irregularities of consumption without much change in the head, but on the other hand it does not supply any extended storage, as if the flow from above was entirely cut off the drawing down of 1 ft. would furnish water to supply the power requirements for only a little over 4 hr.

The power requirements of the mines, though somewhat variable, have been averaging about 2,400 h.p. The Menominee river furnishes this amount of power at what may be considered the normal stage. In dry seasons the water power has to be supplemented, and therefore a 1,500-kw. steam turbo-generator has been installed at the principal mine. This is sufficient in itself to take care of the pumping, if for any reason the hydro-electric plant should be out of commission. As a matter of fact, this has occurred without control only four times in six years, three times on account of anchor ice, not over 8 hr. at either time, and once for 3 hr. on account of a break in the transmission line due to a faulty disconnector. The protection against anchor ice is the length of the pond, which is about 5 miles to the next rapids above. As soon as this pond freezes over the anchor ice formed above does not come through. The three experiences with anchor ice were on days late in the fall before the pond had frozen over, when the temperature fell much below the freezing point and there was a high wind.

At the falls the generating units are of 1,500 and 2,000 kw., 6,600 volts, and are run singly or together according to the mine requirements and the quantity of water available. During the years 1911, 1912 and the first half of 1913, there was generated at the falls 37,502,160 kw-hr. at a cost, including taxes, of 0.083 c. per kilowatt-hour. The steam plant generated 1,670,700 kw-hr. at a cost, including stand-by expenses, of 1.821 c. per kilowatt-hour. The average cost of power for operating was 0.157 c. per kilowatt-hour. Depreciation for a 20-year period and interest at 5 per cent. add 0.182 c., making the total cost, including operating, taxes, and depreciation, 0.339 c. per kilowatt-hour.

At Republic the small water power is used entirely for compressing air. Electricity is used for the pumping, one surface tram, the crusher plant, and the shops. The principal generating unit is a mixed-pressure steam turbo-generator which runs on the exhaust steam of the hoisting engines supplemented by live steam. The exhaust steam is passed through a regenerator in order to distribute its use to as great an extent as possible during intermissions of hoisting. The successful utilization of intermittent supplies of low-pressure steam depends very largely on having the regenerator capacity of ample size. The steam turbine runs at 9,000 rev. per minute. Live steam is automatically supplied to fill any deficien-

cies in the amount of exhaust steam available. There is an independent condenser which produces a vacuum of 27 in. Geared to the shaft of the steam turbine are two electric generators of a combined capacity of 150 kw., which run at 900 rev. per minute. These are to have fly wheels on the shafts so as to eliminate the peaks and reduce the heavy voltage fluctuations. Each wheel is 52 in. in diameter by 10 in. thick and weighs something over 5,000 lb. The speed of the turbine when using live steam is $3\frac{1}{2}$ per cent. less than when using exhaust. These fly wheels will give, for this reduction in speed, 525 h.p-sec. There is a back pressure on the hoisting engines varying from a maximum of 4 lb. to a slight vacuum. As close as can be figured, this turbine is furnishing a kilowatt-hour for a fuel cost of 0.15 c.

Electric Pumps

At the time when the original installation at Vulcan was under consideration, centrifugal pumps for high heads had not given good satisfaction in this country. There had been difficulties with thrust bearings and considerable doubt about continuous efficiencies. The correctness of the general mechanical principle of attaching a centrifugal pump directly to a high-speed motor was recognized. It was decided, therefore, to place the order for the main pumping units of centrifugal design under specifications to cover the principal requirements. In brief, these were for three units, each with an induction motor for 2,200 volts, 450 h.p., three-phase, alternating current, and a centrifugal pump in eight stages, four on each side of the motor, all on the same shaft, with a marine thrust bearing at each end, for a capacity of 900 gal. per minute at a speed of 1,200 rev. per minute, with suction lift of 20 ft. and discharge head including friction of 1,275 ft., with a combined efficiency of motor and pump of 63 per cent. Two of these units were put in at the West Vulcan C shaft and one at the East Vulcan No. 4 shaft. A view of the two pumps at West Vulcan in the pump station 1,200 ft. below the surface is shown in Fig. 1.

When the pumps were started they fell short of the guaranteed efficiency; there was trouble from heat in the thrust bearings in starting, and rapid wear of the protecting sleeves about the shaft in the high-pressure stuffing boxes. The principal changes were in closing some holes in the impellers that had been made with the expectation that they would equalize the thrust movement; in substituting for the marine thrust bearing a hydraulic thrust ring against which the pressure of water in the column pipe is automatically applied by a slight thrust movement of the shaft; in some alterations to make it easier to change the wearing sleeves on the shaft; and in experimenting with different kinds of packing. The result of this work was the raising of the efficiency to the required standard, the elimination of all thrust trouble, and a reduction of the

wear caused by the packing in the high-pressure stuffing boxes to very moderate proportions. Subsequently some further improvements were made.

Multi-stage centrifugal pumps consist of impellers attached to the shaft and stationary diffusion rings. The water enters an impeller near the shaft and issues with great velocity from its periphery. It then passes in a spiral direction through the passages of a diffusion ring to the inlet of the succeeding impeller or from the last impeller to the outlet. The expanding passageways for the water through the diffusion ring convert

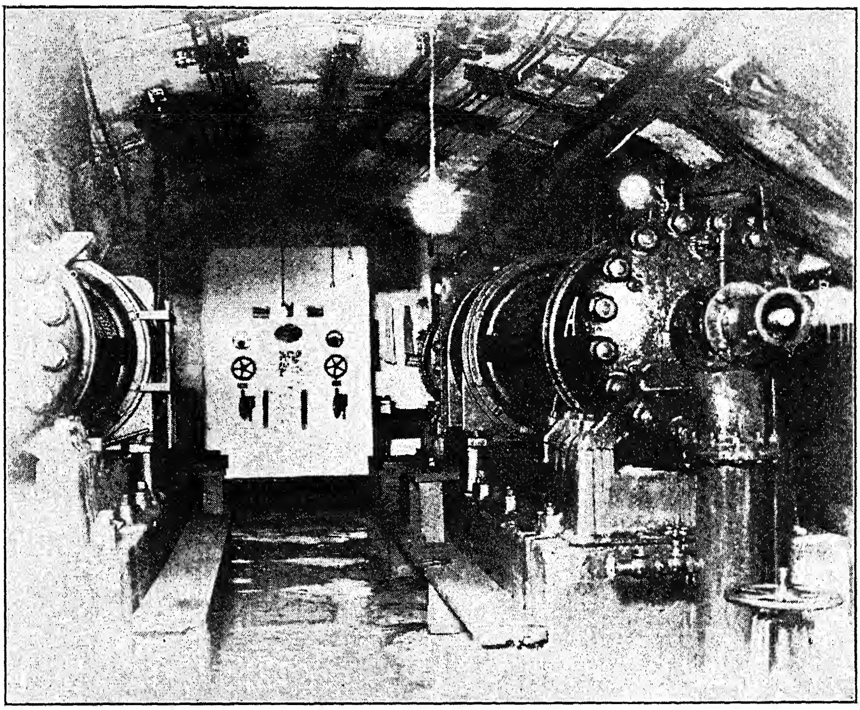

FIG. 1.—PUMP STATION AT WEST VULCAN.

the velocity into pressure. The efficiency of a centrifugal pump depends principally on the shape and size of the impellers, the internal leakages, and the friction in the water passages.

The three original centrifugal pumps are made with a solid casing and the impellers and the diffusion rings are drawn out through the end of the casing. In the pumps installed since there is no casing, but the stationary parts of each stage are held together by large through bolts. None of the pumps have casings divided horizontally, which plan introduces unfavorable joints and necessitates disconnecting and lifting out the shaft and

impellers. Without the horizontal joint the diffusion rings and impellers are very easily drawn out endways without disturbing the shaft. It takes about 4 hr. to take a pump of four stages apart and put it together again.

The experience of several years shows that there is very little wear in the interior or on the periphery of the impellers, or in the water passages leading from one impeller to another. The principal wear and the occasion of greatest loss in efficiency is between the impellers and the diffusion rings. Originally, the contact faces were quite narrow, only

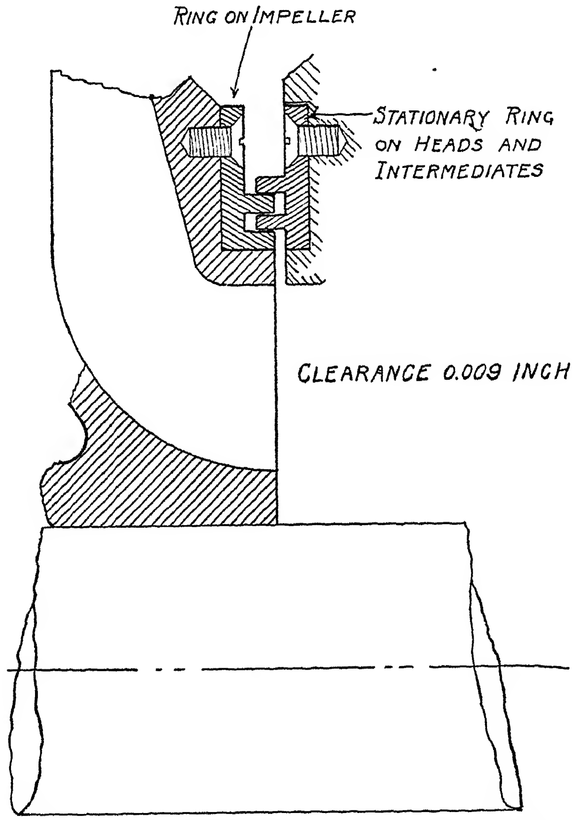

FIG. 2.—LABYRINTH RINGS TO DECREASE LEAKAGE.

$\frac{7}{8}$ in. They have since been made $1\frac{7}{16}$ in. and the tendency to leak has been decreased by using labyrinth rings, as shown in Fig. 2.

In later installations the hydraulic thrust ring was supplied with oil from a separate small motor-driven plunger pump. When oil was lacking it was found that water answered equally well. The advantage of having pressure independent of the water column is because the greatest tendency to thrust is on starting before the impellers become balanced, as they are when under the full head, because at the time of starting the column pipe

may not supply the requisite or perhaps any pressure, and also because the independent pump gives a constant quantity at a variable pressure depending upon the thrust.

The main stuffing boxes were originally packed with a solid metallic packing, but, as that did not prove satisfactory, soft metallic packing and several kinds of special packings were tried in succession, but finally practice has settled down to a good grade of square braided hemp packing. The leakage is naturally greatest through the stuffing box on the discharge end of the pump, where there is the full pressure of 552 lb. to the square inch. As the shaft has only a rotary motion, when the packing is tightened up there is nothing to distribute the pressure applied upon the outside ring of packing to the other rings, as a shaft with motion lengthways helps to do, and consequently the outside ring is apt to be pressed so tight that it wears a groove in the shaft or the protecting sleeve about the shaft. No attempt is made to lubricate the packing. The shaft is protected from this wear in the stuffing boxes by removable sleeves. It takes only 2 hr. to replace a sleeve. The replacing of the sleeves has been the greatest source of delay of a mechanical nature, but the aggregate of the delays is very small. At the East Vulcan mine, where for nearly three years there was only one electric centrifugal pump, and it was run as nearly continuously as possible, the total delays amounted to only 346 hr. in 33 months, or less than $1\frac{1}{2}$ per cent. of the time.

Occasionally the discharge of the pump has fallen off, due to chips or refuse in the suction end of the pump. This is guarded against as much as possible by having duplicate wire screens in the suction tank, so that all the water from the mine has to pass through a screen. The screens are in duplicate, so that there may always be one in place when the other is raised for cleaning. In these mines it has been found that the best protection against grit in the water is to be had from good ditches which keep the water in the drifts below the traveled road. The internal wear of the water passages due to grit has been exceedingly small. The water is free from acid and without corrosive effect. The internal construction of these pumps is simplicity itself, and their dependability is much greater, and the time and cost of repairs much less, than with the triple-expansion steam pumps which the centrifugals displaced.

Approximate figures on the maintenance for one year of four centrifugal pumps as compared to four triple-expansion steam pumps doing practically the same duty are as follows:

	Centrifugal	Steam
Shop labor	$717	$760
Labor on pumps	690	590
Supplies	503	2,021
	$1,910	$3,371

The motors of these pumps have wound rotors with a device for short circuiting the secondary current and relieving the brushes from wear by lifting them from the rings. These pumps were rated at 900 gal. per minute and that was about the quantity of water that they handled at first. Soon after the quantity to be pumped increased to 1,100 gal. per minute. This was too much for one pump and not enough for two, so that it was necessary to start and stop one pump frequently. As this quantity of water continued for some time, it was found that by increasing the speed of the generators at the falls from 60 to 62½ cycles per second, the pumps were each capable of handling from 1,200 to 1,300 gal. per minute. This overloaded the motors, and after running for a considerable time it was found that the insulation had been baked until it was brittle. This made trouble when it became necessary to repair the windings. A dropping off in efficiency will also overload the motor, so that it is well to have centrifugal-pump motors of a larger size than the specified head and quantities under normal conditions call for.

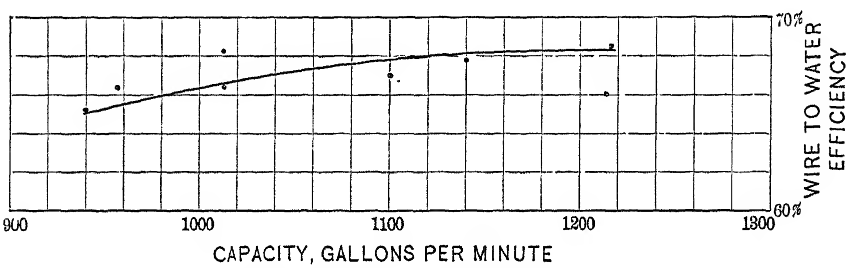

FIG. 3.—EFFICIENCY CURVE OF 8-IN. EIGHT-STAGE CENTRIFUGAL PUMP.

Fig. 3 shows an approximate curve of efficiency based on eight tests at different quantities on a pump when in first-class condition. During these tests the unit was being run at 1,235 rev. per minute and the quantity was varied by manipulating a valve on the suction.

In order to test the efficiency of the pumps it was necessary to measure the water. At first, this was done on surface, by means of both a tank with knife-edge orifice and a weir. Permanent concrete tanks were later installed at both East Vulcan and West Vulcan so as to obtain a continuous record of the amount of water pumped. One of these tanks is shown in Fig. 4. There is a division wall in it which is pierced with a great many 2-in. holes. The water from the mine flows into the back part of the tank and through the holes in the division wall into the front part of the tank. This breaks up the flow of water and prevents "velocity of approach" to the orifice. In the front wall of the tank there is a plate of steel with a circular knife-edge opening of exact size.

The quantity of water that flows through the orifice depends on the head above the center of the orifice. The head is recorded on a recording

water-level gauge and tables for each orifice show the gallons per minute corresponding to each tenth of a foot of head. One of the charts is shown in Fig. 5. This chart was used in connection with an orifice having a diameter of 7 in. and shows an average for the week of about 894 gal. per minute. When the pumping is irregular the average is ascertained by the use of a planimeter for circular charts. On this chart it can be seen that the pumps were stopped for a few minutes three times during the week. The charts are changed Sundays at noon. Orifices of different sizes are used when the quantity of water changes, so as to keep the water at somewhere between 2 and 4 ft. above the center. With these permanent

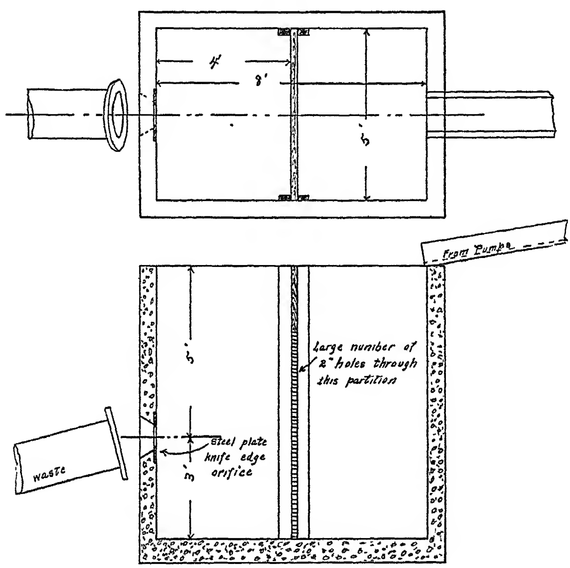

FIG. 4.—MEASURING TANK.

measuring tanks and suitable electrical instruments a test of efficiency becomes a very simple matter.

At the Brier Hill shaft, where there are only from 30 to 40 gal. per minute, and a depth of 900 ft., there is a motor-driven reciprocating, horizontal, plunger pump, of 125 gal. per minute capacity, which on Sundays and holidays may be operated from the hoist house on surface, the high- and low-water mark in the sump being provided with an electric signaling device to the hoist house.

At the Republic mine, for pumping from a depth of 1,150 ft. a motor-driven triplex plunger pump of 95 gal. per minute and a motor-driven horizontal duplex plunger pump of 125 gal. per minute are used, but at that point the maximum water is only 150 gal. per minute, with an average of about 50 gal. At other points where the quantities are moder-

ate and intermittent operation is not objectionable, motor-driven plunger pumps are used.

In the smaller sizes centrifugal pumps are inefficient, but the efficiency increases with the size. Pumps of 600 to 1,200 gal. a minute can be easily maintained at an efficiency of 55 to 65 per cent., measured from the

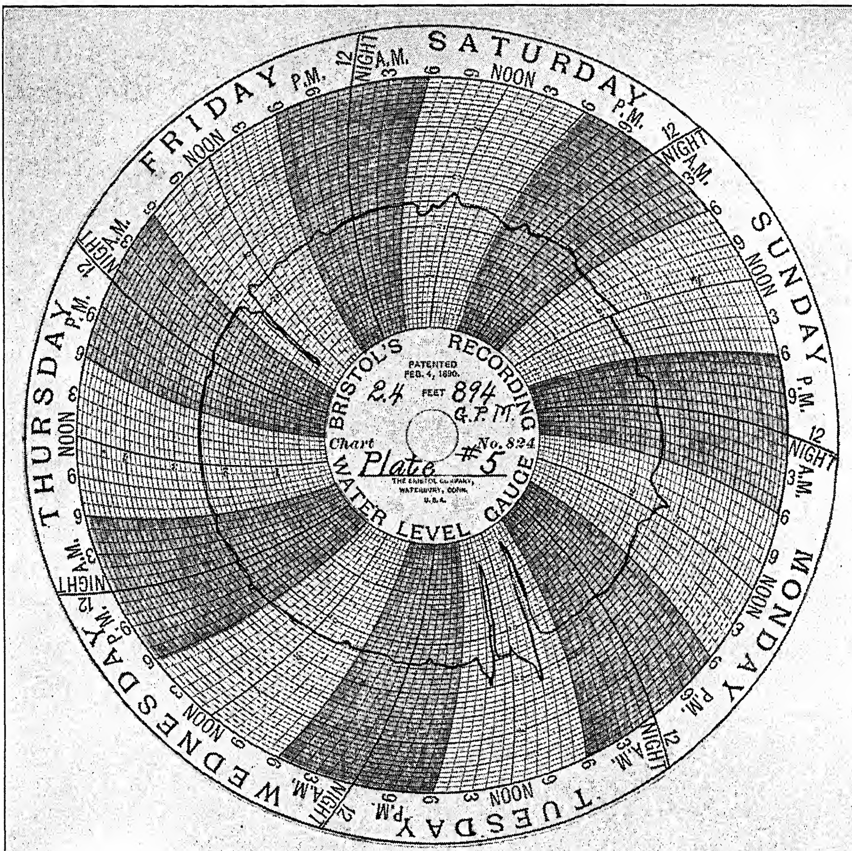

FIG. 5.—CHART FROM RECORDING WATER-LEVEL GAUGE.

power delivered to the motors to the water at the top of the shaft, while pumps of larger capacity will undoubtedly give higher efficiencies.

One of the great advantages of centrifugal pumps is that the quantity of water can be regulated within comparatively wide limits by simply opening and closing a valve on either the suction or the discharge pipe, preferably the former, with but slight variation in the efficiency. A reciprocating pump driven by an induction motor, on the other hand, must run at a constant speed. Mechanical devices to change the speed

of the pump or the quantity of water per stroke are necessarily complicated. The common practice for decreasing the quantity is to use a by-pass on the discharge column, allowing a portion of the water to return to the sump. This of course is directly at the expense of efficiency. Intermittent pumping necessitates adequate sump capacity. It may be generally said that a reciprocating pump driven by an induction motor is especially suited to pump a certain amount of water against a head that may be varied at pleasure, while with a centrifugal pump the quantity of water can be regulated but the head cannot be materially changed without structural changes. To effect the latter end a centrifugal pump should be designed for changing either the number or the diameter of the impellers. High-pressure centrifugal pumps are usually designed for a head of 100 to 150 ft. for each stage or impeller. The speed must be approximately 1,200 or 1,800 rev. per minute with a six- or four-pole motor and a 60-cycle alternating current. With a 25-cycle current the speed would not be sufficient, except with a two-pole motor.

Electric Hoists

Before the introduction of electricity, hoisting at the Penn mines was done at five shafts with steam hoists of the following types:

Shaft	No. of Drums	Diameter feet	Geared	Position of Drums
East Vulcan No. 4	2	10	Yes	Tandem
East Vulcan No. 3	2	5	Yes	On same shaft
West Vulcan C	2	12	Yes	Tandem
West Vulcan C	2	12	No	On same shaft
Curry No. 1	2	6	Yes	On same shaft
Norway No. 10	2	5	Yes	On same shaft

The principal hoisting was at East Vulcan No. 4 and West Vulcan C shafts. The geared plants at these two points were altered so as to permit their being driven by motors. This was done by extending the pinion shaft on the side opposite to the steam engine and putting on the extended shaft a large rope wheel, which was driven by an American system rope drive from a small rope wheel on the shaft of the motor. On the other side the connecting rod of the steam engine was disconnected. This arrangement is illustrated in Fig. 6. The method of operating is to start the motor, rope wheels, gear wheels, and drum shafts and when these are up to speed gradually to apply the clutch of the drum, thus starting the skip or cage and quickly accelerating it. This had always been the practice in starting with steam except that with the rope wheels and motor the fly wheel effect is greater.

At the same time the East Vulcan No. 3 hoist, which was used very intermittently and principally for depths of only 250 ft., was run by

compressed air generated by a motor-driven compressor. As the work of this hoist has increased a motor and belt have been substituted for the engine, as shown in Fig. 7. The same change was made with the Norway hoist. The first-motion steam hoist at West Vulcan has been dispensed with. The Curry hoist was formerly run by steam from the saw mill. This hoist was too small for the work and has been replaced by a new

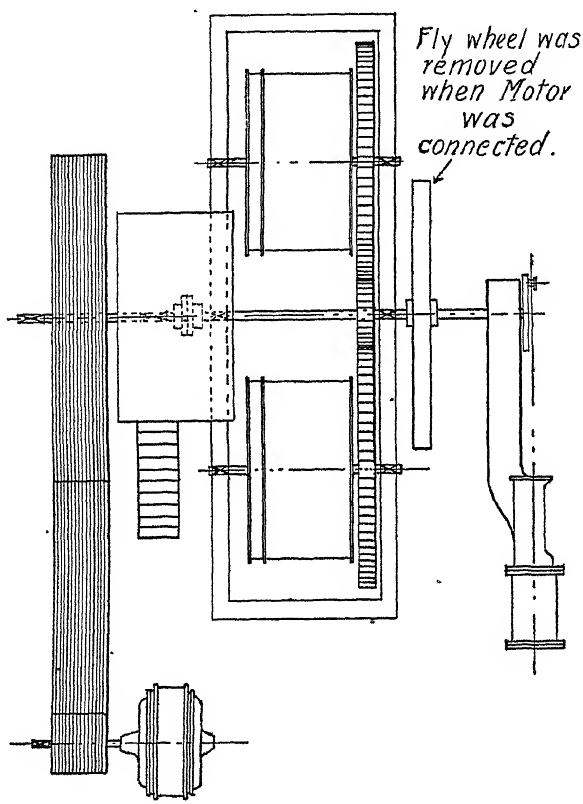

Fig. 6.—Tandem Drums Driven by Either Engine or Motor.

electrically driven plant. A new hoist has also been supplied for the circular concrete-lined shaft at Brier Hill. These last two hoists will be described more in detail.

The motors of the four principal hoists are all of standard design. They are three-phase, 60-cycle, 2,200-volt induction motors with wound rotors and external resistance for starting.

Experience shows that the motors at West Vulcan, Curry, and Brier Hill are much larger than is required. A motor of 200 h.p. would be sufficient for the requirements of any of the above shafts.

	Horse-power	Revolu-tions per Minute	Skip Load Pounds	Present Maxi-mum Travel of Skip	Speed of Skip or Cage per Minute Feet
East Vulcan No. 4....	200	360	6,700	1,557	590
West Vulcan..........	350	360	6,000	1,546	588
Curry................	350	360	12,000	1,410	600
Brier Hill...........	450	300	12,000	989	600

The first hoist at these mines constructed solely for electric hoisting was installed at the Brier Hill shaft. This hoist has two drums with

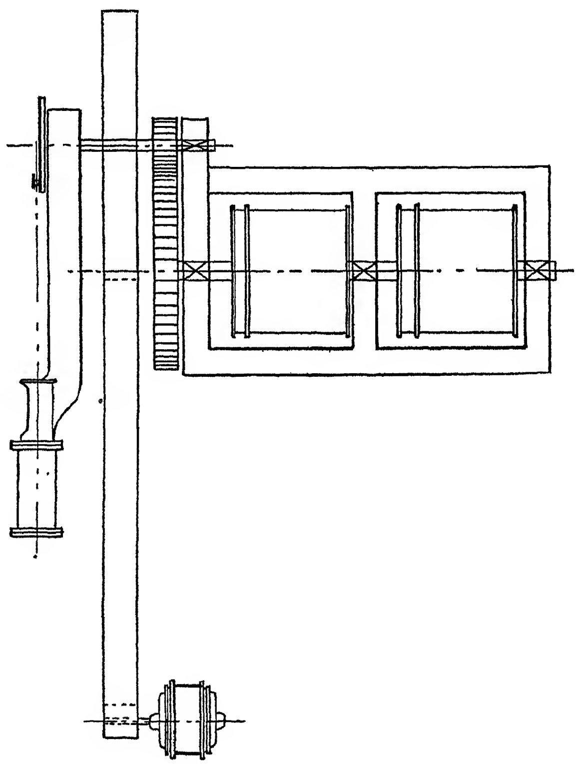

FIG. 7.—PARALLEL DRUMS DRIVEN BY EITHER ENGINE OR MOTOR.

shells of steel plate 12 ft. in diameter by 5 ft. 9 in. face, and two cast-iron conical drums, of which the small diameter is 4 ft. 6 in. and the large diameter 17 ft. These drums, Fig. 8, are keyed on two parallel shafts, a cylindrical and a conical drum on each shaft. Each cylindrical drum is driven by a Lane friction clutch from a cut spur gear having 144 teeth, 4-in. circular pitch and 12-in. face. The pinion has 46 teeth, giving a gear ratio of 3.13 to 1. On the pinion shaft is a rope wheel 21 ft. 6 in. in diameter, having 24 grooves for $1\frac{1}{4}$-in. manila rope. The pulley on the

motor is 48 in. in diameter. The friction clutches and band brakes are operated by compressed-air cylinders each having an oil cylinder to prevent jumping and to hold it at any point. Safety devices on this hoist fulfill the same conditions as those on the Curry hoist, but are more complicated and will not be described in detail here.

Before putting in this plant it was thought that a hand-operated controller for so large a motor as 450 h.p. would be hard to handle, so an automatic controller operated by alternating-current solenoids with a master controller was installed. This controller required frequent atten-

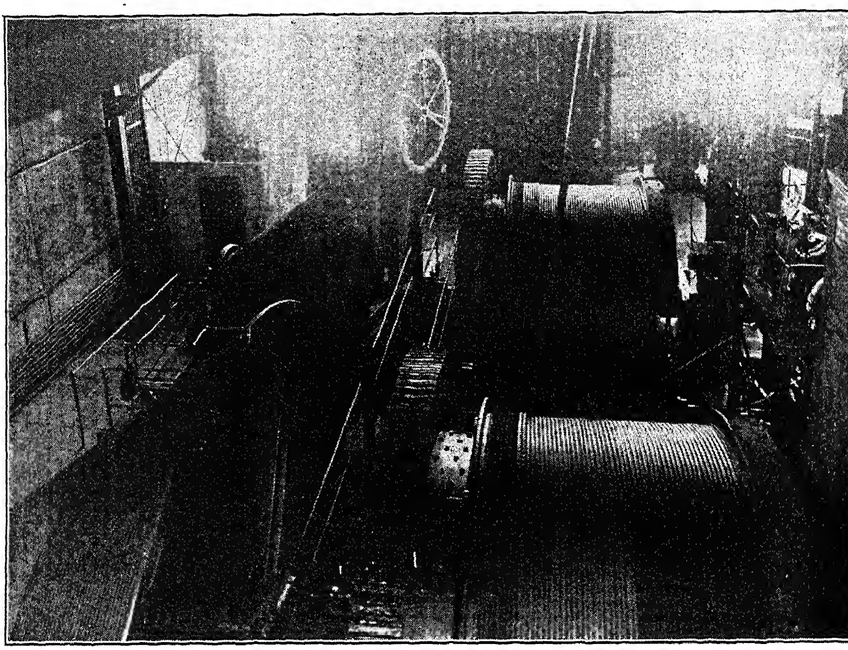

Fig. 8.—Hoist at Brier Hill Shaft.

tion and was very noisy. It has been replaced with a water rheostat, which after some experimenting was built as shown in Fig. 9. The tank is of concrete, open on top and nearly full of a weak solution of carbonate of soda. A timber crosshead is suspended above the tank and to the under side of it four iron plates are attached. The plates are connected to the three secondary leads from the motor as indicated in the drawing. The crosshead and plates are raised and lowered by a rope which leads from an air cylinder in the hoist house. The plates are trapezoids in shape with the shortest side down and they are set at angles to each other so that the lowest parts are the greatest distance apart. As the plates descend into the water the areas increase rapidly and the parts at the

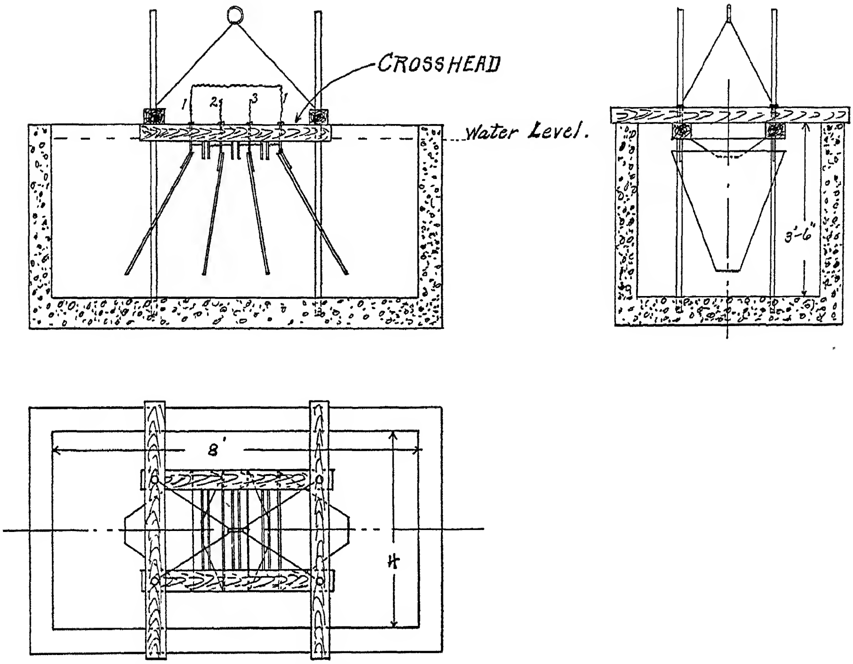

FIG. 9.—WATER RHEOSTAT CONTROLLER FOR 500-H.P. INDUCTION MOTOR HOIST SERVICE.

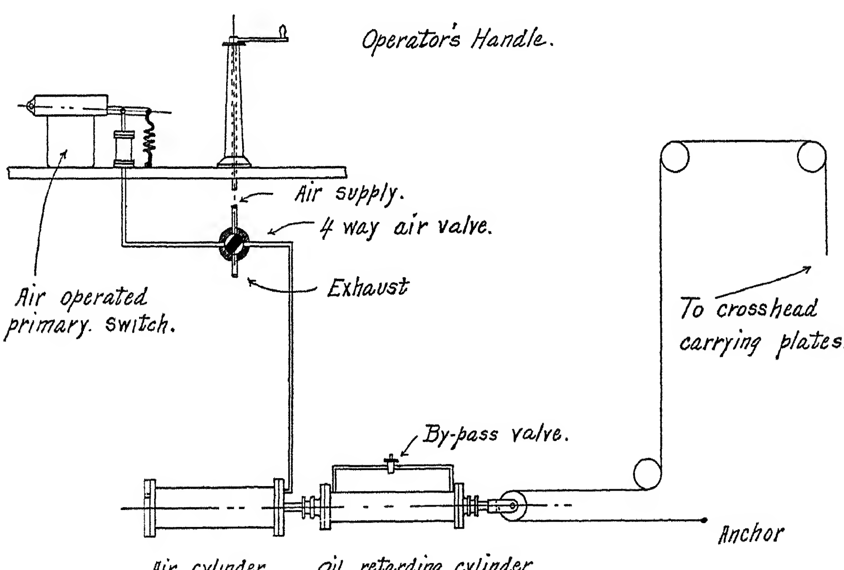

FIG. 10.—OPERATING MECHANISM FOR WATER RHEOSTAT.

surface of the water are closer together, so that the electrical resistance is reduced. The setting of the plane of the plates at an angle with the perpendicular also stirs up the solution to some extent. Between each pair of plates are smaller plates much closer together, electrically connected to the large plates, and at such a height that they enter the water just as

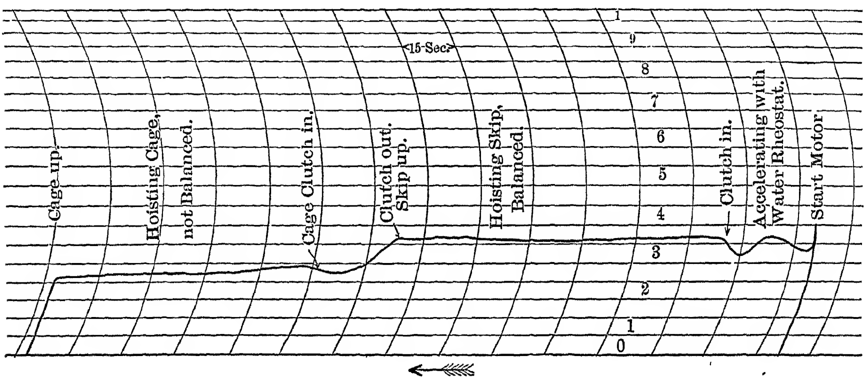

FIG. 11.—STARTING CURVE WITH WATER RHEOSTAT.

the large plates become completely submerged. By adjusting the distance between these small plates the amount of slip of the motor when pulling full load at full speed can be varied.

The mechanism for regulating the speed with which the plates are

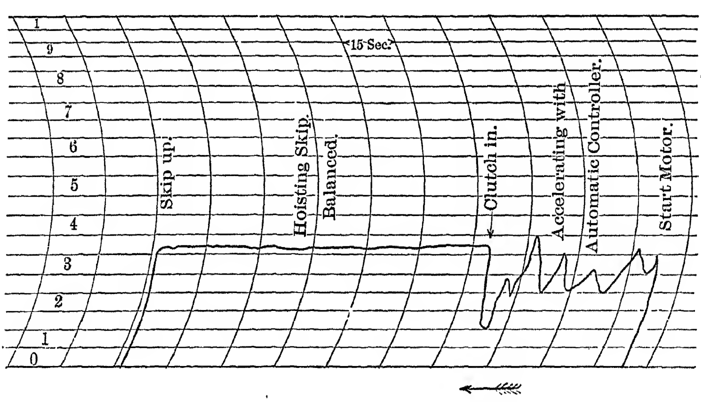

FIG. 12.—STARTING CURVE WITH AUTOMATIC CONTROLLER.

lowered into the water, for raising the plates out of the water, and for operating the primary switch is shown in Fig. 10. A four-way valve having only two positions, "on" and "off," is handled by the operator. In the "on" position air is admitted to a small cylinder which closes the primary switch, and the pipe leading to the air cylinder is opened to

exhaust. The weight of the crosshead and plates causes them to sink into the water at a speed determined by the amount of opening of the by-pass valve on the oil cylinder. When the hoist is nearly completed the operator throws the handle to the "off" position. This allows the air in the primary switch cylinder to exhaust, thereby opening the switch, and at the same time admits air into the air cylinder, thus raising the plates nearly out of the water.

Fig. 11 shows the starting curve with this water rheostat. Fig. 12 shows the corresponding curve with the automatic controller previously

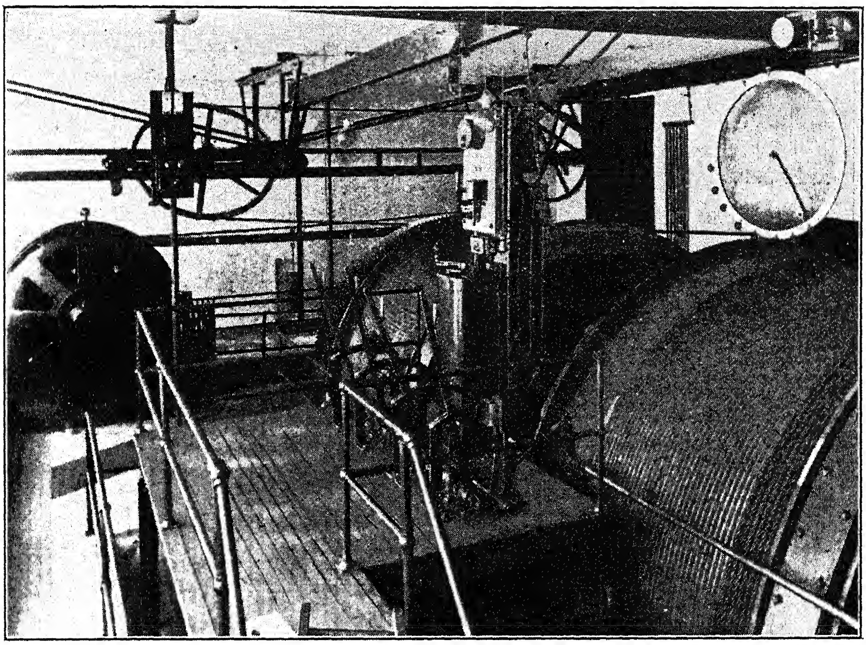

Fig. 13.—Hoist at Curry Shaft.

used. On comparing these it will be seen that acceleration was accomplished with the water rheostat in 20 sec., while it took 40 sec. with the automatic controller, and the power drawn from the line was much more uniform with the former. The curve in Fig. 11 also shows the practically perfect counterbalancing of the skip and the unbalanced load of the cage.

The Curry hoist, shown in Fig. 13, was designed and built by the Penn Iron Mining Co. It has been in service since March, 1912. It has two cast-iron drums 12 ft. in diameter by 6 ft. face on the same shaft, each drum having a band brake 10 in. wide, 12 ft. in diameter, and driven

independently by a Lane friction clutch 12 in. wide, which grips a friction ring 10 ft. 4 in. in diameter.

The main shaft is driven by a Falk cut helical gear having 181 teeth, $1\frac{1}{4}$-in. circular pitch, and an 18-in. face. The pinion meshing with this gear has 19 teeth, giving a gear ratio of 9.52 to 1. On the pinion shaft is a rope wheel 9 ft. 10 in. in diameter having 24 V-grooves for $1\frac{1}{4}$-in. manila rope. The rim of this rope wheel is $3\frac{1}{8}$ in. thick, to give it the proper amount of inertia. This rope wheel is driven from the 350-h.p. motor by a rope pulley 50 in. in diameter.

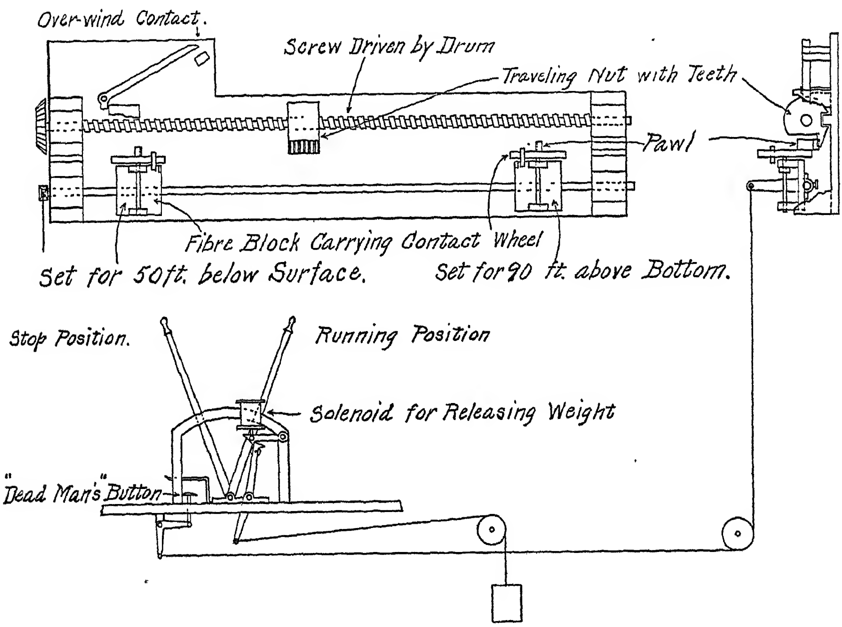

Fig. 14.—Safety Device on Hoists.

The friction clutches and band brakes are power operated. In the basement is a small motor-driven triplex pump which takes oil from a suction tank and pumps it into a pressure tank. When all the oil in the system is in the pressure tank it is only one-third full of oil, two-thirds of the volume being compressed air at 80 lb. gauge pressure. As fast as oil is used and exhausted into the suction tank the pump puts it back into the pressure tank. When there is no oil in the suction tank the pump draws air, which is compressed and delivered into the pressure tank. A small safety valve allows the escape of any excess air. The brake is released by an oil cylinder and set by a weight, oil being admitted or exhausted by a three-way valve. The hand lever operating this valve is connected differentially to the brake lever so that the brake follows the operator's hand. The clutch is engaged by an oil cylinder and released

by a weight in the same manner. The use of oil under pressure instead of compressed air or steam insures smooth action of the clutch and brake, making sudden starting or stopping almost impossible, while the use of weights to release the clutch and set the brakes insures a reliable source of power for stopping.

The safety device stops the drum under any one of four conditions, viz.: Lowering too rapidly; overwinding; at a point 90 ft. above the bottom when lowering; and at a point 50 ft. below the surface when com-

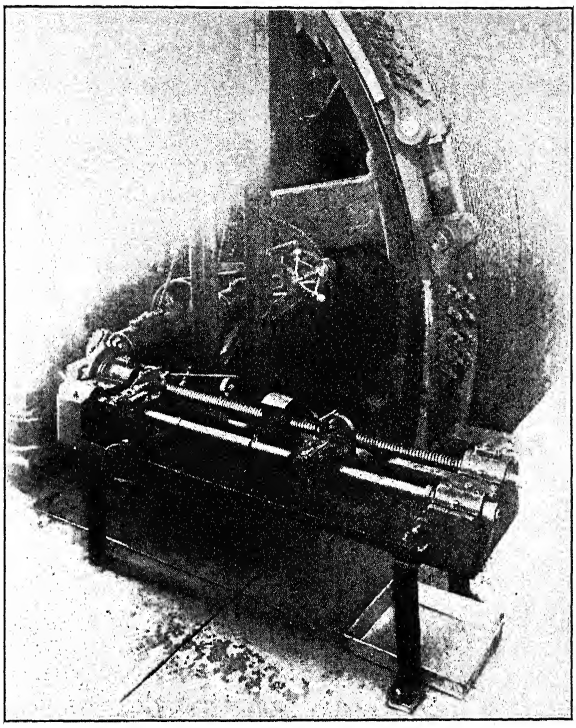

FIG. 15.—SAFETY DEVICES.

ing up. The two latter stops are under the control of the brakeman, so that if he is aware of the position of the cage or skip he can disconnect either of these two devices. Referring to Fig. 14, the levers which operate the valves of the clutch and brake cylinders are shown, one in the "running" position and one in the "stop" position. A solenoid is arranged to release a weight which puts both clutch and brake levers into the "stop" position. It remains then to have a contact made that will send a current through the solenoid when it is desired to stop the drum. The contact for stopping when lowering too rapidly, the condition first mentioned, is made by a simple fly ball governor, shown

in Fig. 15. The other three conditions are controlled by means of the device shown in Fig. 14. A screw, driven by the drum, carries a nut with teeth which strike a pawl on the contact wheel, turning the wheel slightly and thus making a contact. By slightly turning the shaft which carries the contact wheels, the pawls are lifted and the nut travels under without turning the wheel. The shaft may be turned by pressing on the "dead man's button." The contact for the overwind needs no description. Fig. 15 gives a general view of this safety device. This device has been tried many times and all of the four conditions have always been met.

The ore formations at Vulcan are inclined at varying angles from 45° to 90° from the horizontal, but all the shafts are vertical with the

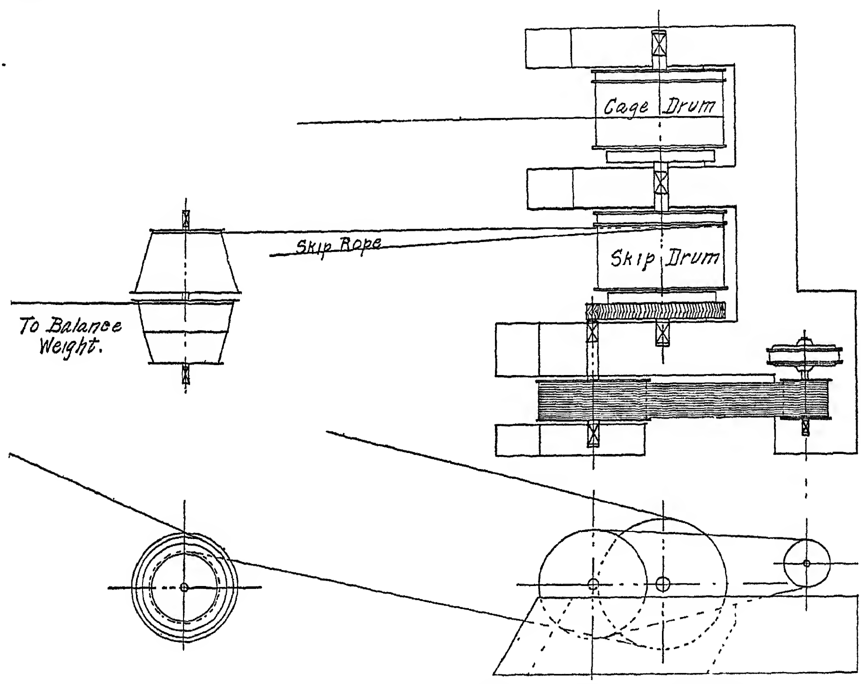

Fig. 16.—Arrangement of Curry Hoist and Balance Drums.

exception of the lower part of East Vulcan No. 4. The ore bodies are very irregular in shape and may be considered ore shoots rather than lenses. The quantities on different levels vary greatly. For this reason hoisting with independent drums rather than with drums in balance presents advantages. A single drum at any of the shafts will carry all the ore required and work more or less intermittently. This economizes shaft space, and with a plant of two drums one can be used for a skip and the other for a cage.

In the important installations the weight of the skips, and when heavy the weight of the cage, is counterbalanced by a weight in the

shaft. The road for the counterbalance requires very little space in the shaft, as the counterbalance is made fairly long and small in the other directions. In one case an old Cornish pump plunger 16 in. in diameter and 10 ft. long partly filled with scrap has been used.

At East Vulcan No. 4 and Curry, in order to balance and equalize the weight of the ropes, the counterbalance rope, after leaving the hoisting drum, passes outside of the hoisting house to one of two connected conical drums toward its smaller diameter, while from the larger diameter of the other drum another rope leads to the shaft and carries the counterweight, as shown in Fig. 16. The uniformity of the balancing throughout the travel of the skip in the Curry hoist is shown in Fig. 17. In the Brier Hill plant, instead of the pair of conical drums outside the hoisting house there is a conical drum on the shaft with each of the

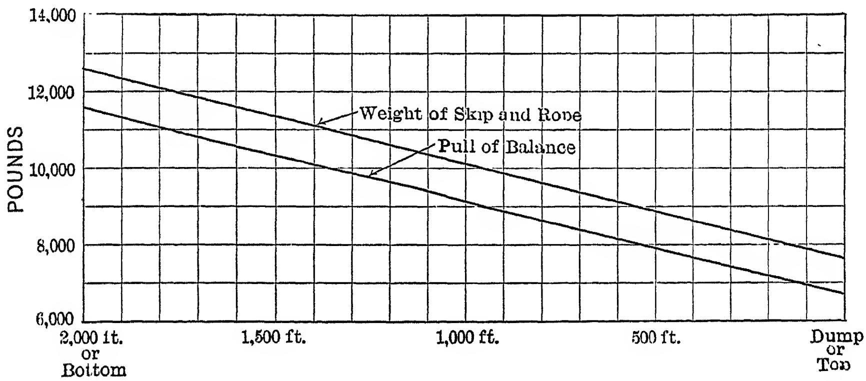

FIG. 17.—CURVES SHOWING VARIATION IN BALANCE WITH CURRY BALANCE DRUMS. $1\frac{1}{4}$-in. hoisting rope, 4,900 lb.; skip weighs 7,600 lb.; weight of counterbalance, 8,260 lb.

main hoisting drums and the counterbalance rope leads from the smaller end of the conical drum (see Figs. 8 and 18). This arrangement is possible only when the hoisting drums are set tandem to each other. The strains on the counterbalance drum are so much less than on the hoisting drum that it can be very much lighter and there are fewer difficulties in its structural features than where conical drums are used for hoisting. The counterbalancing of the ropes by means of a single conical drum necessitates the use of a drum with a wide difference between its end diameters, a difference which in some cases is almost impracticable, and in any case requires deep grooving. Such a drum is more expensive both for itself and for the inclosing building than the pairs of drums used on the other plants and is heavier, thereby increasing the inertia.

In order to equalize the weight of the ropes in every part of the shaft as nearly as possible the angle of the cones must be carefully designed. To obtain absolute equalization would require a cone of which the

outlines of a longitudinal section would be curved rather than straight, but the difference in counterbalancing effect in different parts of the shaft can usually be kept within 100 or 200 lb. with straight cones.

In thus counterbalancing the dead weights some allowance must be made so that the descending skip will overhaul the drums. This requires generally an unbalanced load of not exceeding 800 lb. The excess of weight of the empty skip or cage should only be such as to take it down with little or no application of the brake for the greater part of

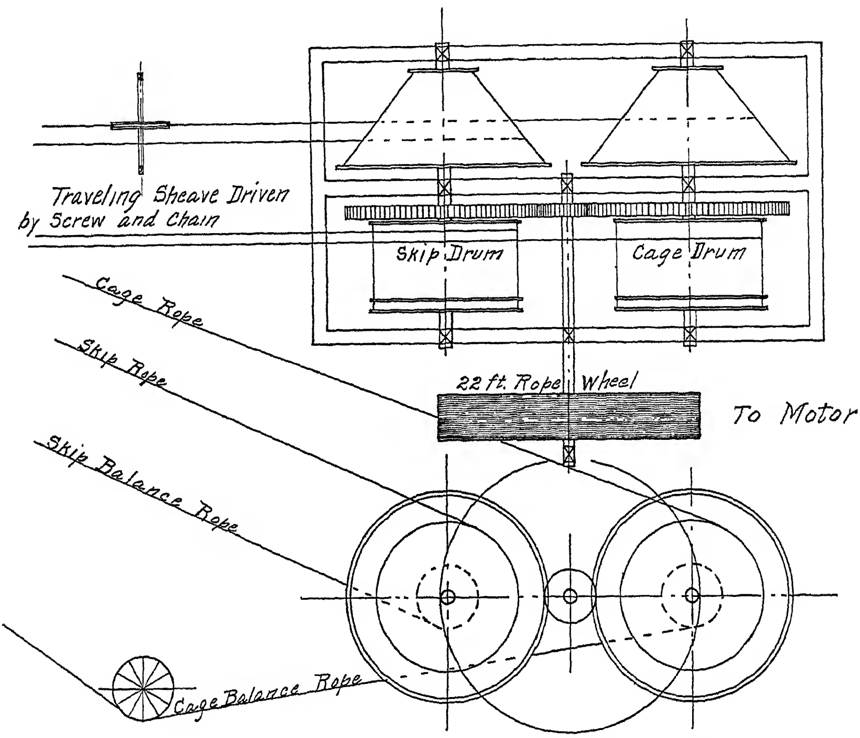

FIG. 18.—ARRANGEMENT OF BRIER HILL BALANCE DRUMS.

its travel. In a shaft 2,000 ft. deep, where the weight of ore hoisted is 12,000 lb., the weight of the skip 7,400 lb., and of the rope 4,900 lb., or a total dead weight of 12,300 lb., the loss, neglecting friction, would be 50.6 per cent. When the dead weights are counterbalanced to within 800 lb. the loss is only 6.6 per cent.

In this method of counterbalancing the conical drums have been designed so that the total travel of the counterbalance will be so much less than that of the skip or cage that the counterweight will never come to the surface when the skip or cage is at the bottom of the shaft. This has been done to avoid the freezing of the counterweight to its guides in severe winter weather.

For a counterbalance recently designed for one of the Republic shafts, in place of the two conical drums there are a nearly cylindrical drum and a reel for a flat rope which carries the counterweight. This method of counterbalancing can be used for a depth of at least 3,000 ft. in a vertical shaft with a load of ore of 12,000 lb., as illustrated in Fig. 19. In Fig. 20 is shown the uniformity of the balancing.

When a skip is in the dump a part of its weight rests on the members of the head frame and it is necessary to make some compensation so as to maintain the equalizing of the weights at that point as well as at other

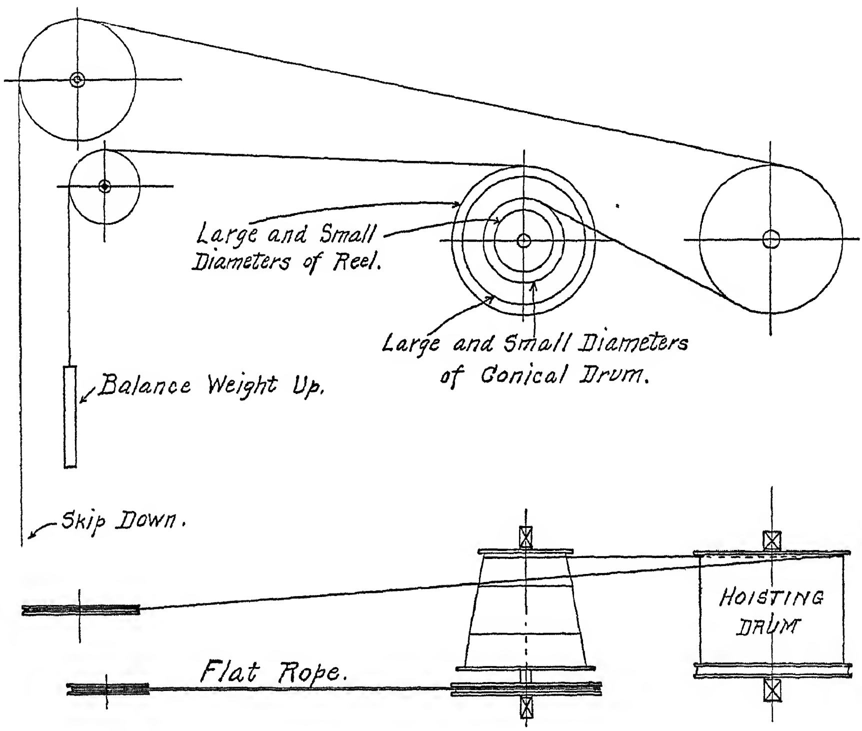

Fig. 19.—Method of Counterbalancing for 3,000-ft. Vertical.

points in the travel. This has been accomplished in several ways. One way was to have the counterweight made in parts, the upper part of larger cross section than the lower part, so that when the skip was entering the dump the larger part of the counterweight near the bottom of the shaft would be caught on stationary projections from the shaft timbers and held there, to be caught up again when the skip came out of the dump. Even with slowly traveling ropes this put on a sudden strain which was not desirable. Another method that has been used is to curve the counterweight road at the bottom so that the vertical component of the weight decreases similarly to that of the skip when it goes into the dump.

This answers the purpose excellently, but the curved road requires additional rock excavation in the mine and is expensive to build and maintain. Also, when new levels are sunk the location of the curve must be changed. No attempt has been made to make this equalization by change in diameters on the conical drums, for like reason. The method which has proved to meet the conditions most satisfactorily is to have the frame of the skip pick up a weight as the box goes into the dump. In order to take the weight gradually and without jar, an idler wheel 36 in. in diameter attached to the top of the bail of the skip engages a rope which lies across the skip compartment just as the box of

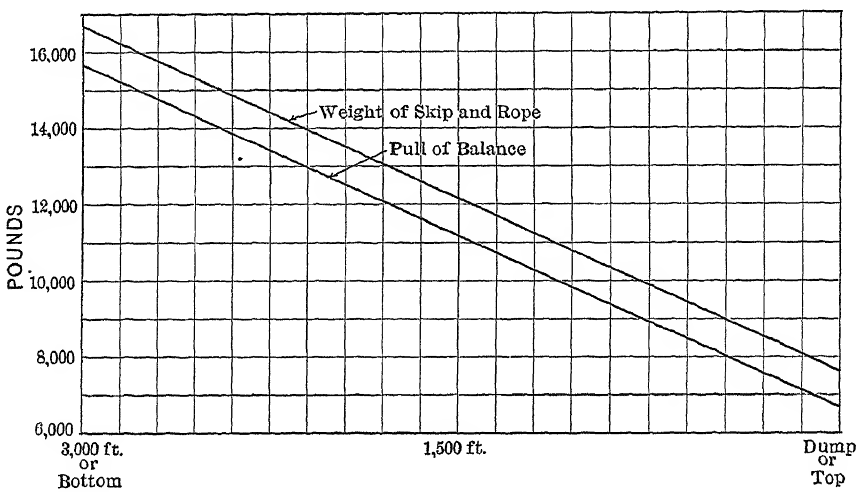

Fig. 20.—Curves Showing Variation in Balance with Reel and Drum. $1\frac{1}{8}$-in. hoisting rope, 9,000 lb.; $\frac{3}{8}$ by $2\frac{1}{2}$-in. flat balance rope, 5,100 lb.; weight of skip, 7,600 lb.; weight of balance, 8,400 lb.; load raised (ore), 12,000 lb.

the skip starts into the dump. One end of the rope is fixed, the other end passes over a vertical wheel and has a weight attached to it. The weight does not hang over the shaft and a fence prevents any one from getting under it. Without this "take-on" balance or a similar device it would not be possible to have the counterweight in the shaft as heavy as it might otherwise be by several hundred pounds. (See Fig. 21.)

The use of a counterweight with independent skips and cages not only reduces the total work but makes the work after the moving parts are up to speed equal throughout the whole of the travel. In hoisting with skips in balance, unless there is a tail rope the weight of one of the ropes is added to the required starting torque, gradually decreases, is balanced half way up and thereafter increases negatively.

In the system of hoisting described the extra power required to start the skip or cage and accelerate it is provided for in the fly-wheel action of the revolving parts, especially in the larger rope wheel. The design is

based on the requirement that the energy stored is sufficient to accelerate the load without reducing the speed below the slip speed of the motor. In this method no resistance is required to reduce the speed, as in the Ilgner system, and that loss is eliminated. The drums are controlled mechanically by means of a clutch and a brake in the same way that has

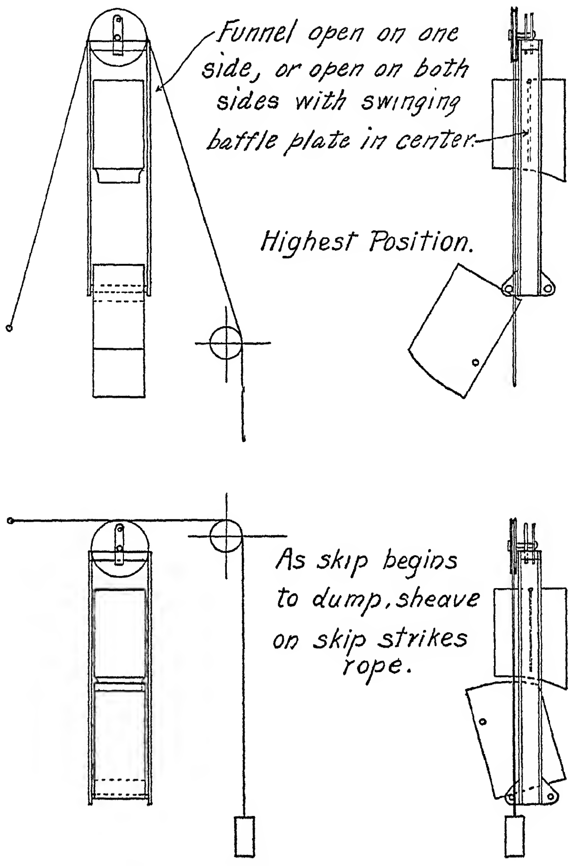

FIG. 21.—"TAKE ON" BALANCE.

been in general practice for years with steam plants of like design. If built with ample surfaces the clutches and brakes are effective and require very little attention. The Brier Hill hoist was started in April, 1910, and has run three years and seven months, hoisting during that time 500,000 tons of ore. The original frictions are still in service. The Curry hoist has run 20 months and hoisted 150,000 tons without requiring a replacement of the frictions. When the counterweights are used the brakes also require very little attention. The control of a drum by means of a mechanical clutch and brake is as simple and exact as can be desired.

This system has the same advantage as the Ilgner system in the fly-wheel

action to prevent any peak load in starting the drum, but the fly-wheel effect is limited to what is sufficient for that purpose and is not intended to provide power to hoist much after the power is shut off. As hoisting at these mines is generally intermittent the practice is to start up the motor when the signal to hoist comes in. It takes about 20 sec. to get it up to speed. Before the skip or cage reaches the top the current is cut off and the travel is completed by means of the momentum of the moving parts. The motor is then idle until there is another call to hoist. When hoisting is irregular the saving over the Ilgner system by not having to keep a heavy fly wheel in motion is considerable. There is also a considerable saving in the mechanical control over the Ilgner control by the omission of the direct-current generator and motor. There is some loss, however, in the mechanical appliances of a clutch and brake, but these probably do not equal the rheostat losses of the other system. It must be admitted that no power can be derived from lowering timber, men, tools and other weights, as in the case of the Ilgner system or with a compressed-air system such as has been recently installed at Butte and described in B. V. Nordberg's paper entitled The Compressed-Air System of the Anaconda Copper Mining Co.[3] No continued record at the Penn mines is available for these lowered weights, but a careful record for a week at one shaft, at which the greatest amount of timber is lowered, shows that the lowered weights are 5.67 per cent. of the weights hoisted. Only a small fraction of this loss could be recovered by either the Ilgner system or the compressed-air system at Butte. The total weight lowered at Brier Hill in a week is less than 250 tons, a distance of 750 ft., and the power wasted costs only 47 c. to generate.

The following figures show the results of tests of hoisting at the Brier Hill and Curry shafts. By "live ton-feet" is meant the live load of ore in tons multiplied by the number of feet hoisted vertically.

Results of Test on Brier Hill Electric Hoist

Date Nov., 1911	Kilowatt-hours	—No. of Tons Hoisted from— 5th Level	6th Level	8th Level	9th Level	Live Ton-feet	Kilowatt-hours per Live Ton-foot
6	563	6	24	195	228	371,424	0.001515
7	578	3	33	183	249	384,579	0.001505
8	558	3	30	180	240	372,480	0.001497
9	597	9	36	168	270	396,162	0.001507
10	615	6	30	183	279	410,853	0.001496
11	287	0	12	75	141	190,671	0.001510
Total	3,198					2,126,169	0.001504

From the 5th level to the dump is 480 ft.; 6th level, 592 ft.; 8th level, 780 ft.; 9th level, 887 ft. Load, two cars or 12,000 lb. of ore. Hoisting speed, 600 ft. per minute.

[3] *Trans.*, xlvi, 826 (1913).

It takes at the rate of 2.256 kw-hr. to hoist 1 ton of ore 1,500 ft. and the cost of power for this work is 0.764 c.

Results of Test on Curry Electric Hoist

Date June, 1912	Kilowatt-hours Integrating Meter	—No. of Tons from— 16th Level	17th Level	Live Ton-feet	Kilowatt-hours Per Live Ton-foot
12	243.75	117	12	169,956	0.001434
13	462.5	210	36	325,440	0.001421
14	481.25	243	18	343,224	0.001402
17	450	258	3	341,694	0.001318
18	456.25	216	24	316,368	0.001442
19	462.5	228	21	327,834	0.001411
20	462.5	222	18	315,756	0.001465
Total	3,018.75			2,140,272	0.0014104

From the 16th level, 1,308 ft. to the dump; 17th level, 1,410 ft. Hoisting speed, 600 ft. per minute. Load, two cars or 12,000 lb. of ore.

It takes at the rate of 2.1156 kw-hr. to hoist 1 ton of ore 1,500 ft. and the cost of power for this work is 0.712 c.

On a capacity test recently made on the Curry hoist 13 skips, or approximately 78 tons, of ore was raised 1,410 ft. in 61 min. This is equivalent to 325,000 to 350,000 tons a year.

From data collected during this test it has been estimated that with a hoisting speed of 1,200 ft. per minute, which is well within safe limits, an output of 300,000 tons per year could be obtained from a depth of 3,000 ft., and greater quantities at less depth. In addition to the very high efficiency of this system of hoisting, the comparatively small cost of the hoisting plant and accessories, the saving in the size of the building to inclose it and the decreased space required in the shaft must be considered.

Electrically Driven Air Compressors

In substituting electrical for steam machinery at the Vulcan mines four compressors were installed. At East Vulcan the compressor is two-stage, having a capacity of 2,200 cu. ft. of free air per minute at a speed of 120 rev., driven by a rope drive from an induction motor of 350 h.p., 2,200 volts at 360 rev. per minute. At West Vulcan two two-stage compressors were put in. Each has a capacity of 3,300 cu. ft. of free air per minute, runs at 72 rev. per minute and is driven by a rope drive from an induction motor of 450 h.p., 6,600 volts at 300 rev. per minute. At Norway a straight-line, two-stage compressor of 780 and 390 cu. ft. of free air per minute was changed by removing the steam cylinder, putting a belt wheel on the main shaft and driving it from a two-

speed induction motor of 100 h.p., 2,200 volts at 600 and 300 rev. per minute. The use of rope drives for the larger compressors and a belt for the small one permitted the use of high-speed motors with comparatively low-speed compressors, and this was less expensive than compressors with motors on the main shaft. The loss in efficiency of the rope drive is 2 per cent., while there is a gain in efficiency and power factor with a high-speed motor over a slow-speed motor.

The rope drives for the compressors and hoists at Vulcan and Republic have been very satisfactory. At Republic one transmission rope has been in use over 10 years, although its continuous service would be only about half that, as the plant consists of two compressors driven by water wheels which do not always run at the same time on account of lack of water.

The experience of the past few years indicates that it would have been a less expensive and more efficient installation if instead of putting in compressors at the three mines they had all been placed at the more central point at West Vulcan with pipe lines to East Vulcan, 1½ miles, and to Norway, 1⅓ miles. If that had been done three compressors, of 1,500, 3,000, and 4,000 cu. ft. of free air per minute, would have supplied all the requirements and could be run as required at nearly full capacity at all times. The pipe lines would have been less expensive than the additional compressor required in the plan adopted.

The varying demand for air is readily met with steam compressors by varying the speed, but with constant-speed motor-driven compressors some means must be used to reduce the quantity of air compressed and the amount of power required. All of the above-mentioned electrically driven compressors have choking inlet controllers. The controllers on the West Vulcan compressors have oil dash pots which allow the inlet to be partly or entirely closed. On each end of the high-pressure cylinder is a valve that connects the two ends of the cylinder when the pressure in the intercooler drops below atmosphere. This by-passes the air and prevents excessive heating such as would result if air were compressed in one cylinder from a partial vacuum to full receiver pressure. The East Vulcan compressor has a choking inlet controller without the oil dash pot, and instead of by-passing the air from one side of the high-pressure piston to the other, it opens each end to the atmosphere when there is a partial vacuum in the intercooler.

Tramming

The output of the Penn mines has averaged for the last few years about 400,000 tons a year, and this comes from several shafts and from several levels in each shaft. There is no ore body of such size or distance from a shaft as to justify the installation of power trams. Considering

the quantities, tramming with mules is satisfactory and economical. On good roads with even grade, a single mule for some time regularly drew loads of six cars, or 12 tons, of ore a distance of 2,500 ft. The maximum load recorded was 13 cars, or about 26 tons.

The ore hoisted during the winter months is stocked on surface. As there are two, three, or four grades at each shaft, it is necessary in summer to transport the ore from the shaft to the different pockets at the railroad. The movement to stock pile or pocket is done by a car with end-

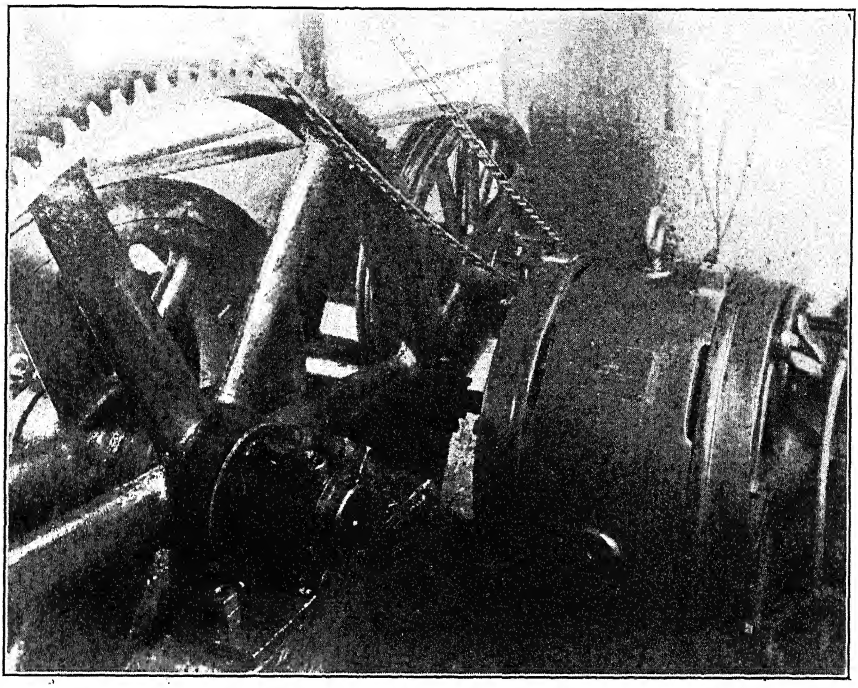

FIG. 22.—TRAMMING PLANT AT THE PENN MINES.

less rope which is moved by wheels geared to a motor. This plant is shown in Fig. 22. The tram is driven by a 20-h.p., 220-volt, 720-rev. per minute, wound-rotor, reversible, induction motor.

The drive wheel is made with a rim in halves that can be easily replaced. The drum has four $\frac{3}{4}$-in. grooves on its outer circumference. About 4 ft. from the center of the drum is a shaft carrying three idler wheels, the center one being keyed to the shaft and the two outer ones being loose on the shaft. This shaft is set at an angle to the horizontal so that the top of one wheel is in line with the first groove of the drum, while the bottom of the same wheel is in line with the second groove on the drum. The rope is led to the first groove on the drum, then around

one idler, to second groove, and so on. Having three separate wheels for the idlers reduces the tendency of wear to cause a differential strain on the rope. The drum being split allows of its being replaced quickly when the grooves show a difference in diameter caused by wear. The load of the car is about 6 tons of ore and there are curves in the track of 25-ft. radius. The trestles used for stocking in winter are taken down as the ore is loaded by a shovel during the season of navigation, and are set up again in the fall. This is considered cheaper than to build out tracks on the ore as it is dumped. It also avoids the necessity of any one going out on the trestle during the cold weather except occasionally to oil the rollers. The danger of derailment does not involve life.

For these reasons and because there has been no other need for direct current a trolley system of tramming has not been considered. The quantity of power is comparatively so small that the question of efficiency is secondary to the other elements.

Signal System

Electric bell signals were originally operated by direct current from primary batteries using one weather-proof wire for each signal (skip,

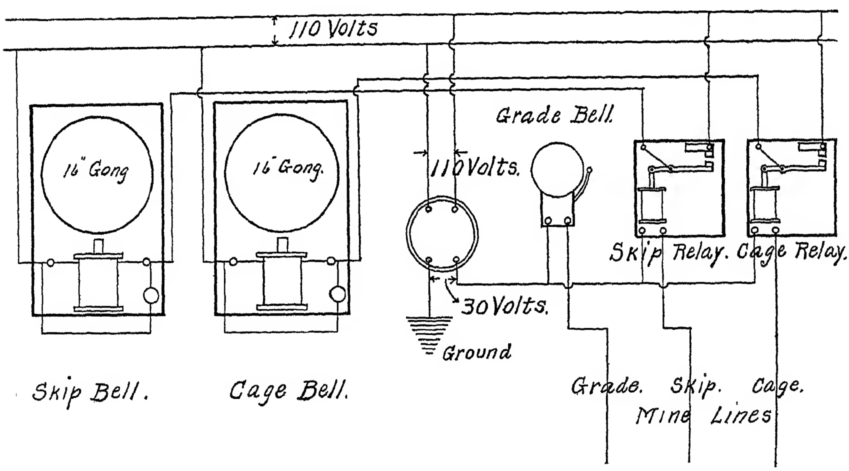

Fig. 23.—Signal System.

cage, or grade) and a common return. So much trouble was experienced, due principally to electrolysis, that, before the general alternating-current system was put in, a telephone magneto was used by plugging in at different levels and ringing by hand. This prevented any one except the conductor for the cage and the dumpers for the skip, who were furnished with magnetos, from ringing any signals, and stopped all trouble from electrolysis.

When alternating current was available the present system, shown in Fig. 23, was developed. A small transformer takes 110-volt current from the lighting system and reduces it to 30 volts. One side of this low-voltage circuit is connected to the ground, while the other side leads to a relay for each of the bells in the hoist house, skip, and cage, and to one side of a grade bell in the shaft house. The other side of each relay and the grade bell are each connected to one of three No. 4 bare copper wires supported on insulators down the shaft. By grounding any one of these three wires a current will flow through the grade bell or relays in the hoisting house. The bell wire for the cage is near the center of one side of the compartment, so that it is nearly impossible to reach it at any landing place unless one stands on the cage. A short piece of flexible wire, with a bare piece of No. 4 solid wire at the end, is fastened to the iron work of the cage, so that the bell wire for the cage can be grounded from the cage at any point whether at rest or moving. This plan prevents any one from ringing the bell for the cage except from the cage itself. The ringing of the cage bell when the cage is not in sight, although against all rules, is occasionally done and is very likely to have serious consequences. It is the practice at these mines to have each cage handling men, timber, and tools in charge of a conductor, whose place generally is riding on the cage.

The skip and cage bells are 16 in. in diameter and are struck a heavy blow by an alternating-current solenoid using a local 110-volt circuit, this circuit being closed by the relay. In addition to ringing the bell very loudly an indicator registers the number of bells rung and a lamp lights. This bell, lamp, and indicator can be seen in Fig. 13.

Power Lines in the Shafts

All current carried underground is 2,200-volt, three-phase, 60-cycle alternating. At the West Vulcan and East Vulcan No. 4 shafts three separate lines of conduit are carried from the surface sub-station to the pump rooms. Each conduit incloses three separate transmission wires, two of the conduits having No. 00 stranded wires and one having 500,000 circular mils stranded cable. Each wire is insulated with rubber for 7,500 volts, the wall being of 30 per cent. Para rubber $\frac{5}{16}$ in. thick. The three wires are supported on strain insulators in the shaft house and at stations about every 500 ft. The conduit is sealed at the upper end around the wires to prevent the entrance of moisture and is open at the lower end to allow the moisture of condensation to get out. The first conduits used at the Penn mines were 3-in. pipe lined with fiber. The inside diameter was so small that it was hard to pull the three wires in and after being used some time the moisture caused the fiber to swell so that it was very difficult to get the wires out. The conduits now

used are 3-in. Sheraduct for the No. 00 lines and 5 in. for the large lines. The first 2,200-volt underground lines, put down one of the shafts at Republic, were lead-covered cables, three cables in an iron pipe. The alternating current seemed to build up a static charge on the lead covering that punctured the insulation as well as the lead and caused bad short circuits. While wires in a shaft or mine are underground in the miner's use of that term, they are really aerial lines, for they are not imbedded in the ground, under which latter conditions lead-covered wires are properly used.

Conclusion

Numerous small motors are used for driving hoists and pumps in winzes, timber hoists, portable saws, concrete mixers, and shop tools. At the Penn mines no steam is used except in the saw mill, for heating, and for supplementing the power from the Falls when there is a deficiency. Electricity has been entirely satisfactory from an operating standpoint as well as very efficient. The same men who formerly operated the steam hoists and pumps operate the electric hoists and pumps. The adaptability and reliability of electrical machinery is generally appreciated.

Discussion

K. A. Pauly, Schenectady, N. Y.—I feel that this paper is especially valuable, because it contains so completely the results of actual experience by two men who have been connected with mining ore for many years.

There are two or three questions which I would like to ask. First, under the subject of "pumping," I notice that by the substitution of electric pumps for steam pumps the cost of supplies has been reduced from a little over $2,000 to a little over $500. I would ask whether that reduction is due to the substitution of electric motors for the engines, or is due to the substitution of centrifugal pumps for the reciprocating pumps?

F. H. Armstrong, Vulcan, Mich.—That reduction is due to the water end of the pump. The high cost of the steam supplies is largely due to the replacement of the brass valves and brass valve seats in the steam pump, in the steam end or motor end.

K. A. Pauly.—With reference to the water rheostat, which differs materially from the standard rheostat used for mining hoist work, what resistance ranges are obtainable, and what is the minimum slip of the motor when running with the rheostat in the minimum resistance position?

F. H. Armstrong.—You can get any resistance, up to so large a point that the motor will not start, by simply reducing the amount of the area

of the plates which is in the water, and the slip can be varied from 20 per cent. down to 6 per cent. by the small slip plates which are illustrated at the top of the main plate. We are running at between 7 and 8 per cent. slip.

K. A. Pauly.—The efficiency, as determined from the power consumption and work done with the hoist, seemed to vary from 57 per cent., over all, to 49 per cent. I would like to ask how much of this 43 per cent. and 51 per cent. of loss is due to shaft loss and mechanical parts, and how much from the hoist coupled to the main motor, if that is known.

F. H. Armstrong.—That is not known.

Benjamin F. Tillson, Franklin Furnace, N. J.—Speaking of the signaling system, I notice it is spoken of as a grounded system. I would ask if any trouble has occurred through what you might call "spook signals," from inadvertent grounding in other parts of the system, or other parts of the power plant. In our alternating-current system at Franklin Furnace, we have occasionally had some "spook signals," although our system is not supposed to be a grounded system, due to the grounding of a line, which was unnoted until such signals were given. Our voltage will run somewhere around 25 or 30 volts through the bell magnets.

F. H. Armstrong.—Our voltage is about the same. We have never noticed anything of the kind.

J. E. Johnson, Jr., New York, N. Y.—I would ask how the efficiency of these electric hoists, of which we have been hearing, compares with the efficiency of the compressed-air hoist system which was applied at Anaconda. The Anaconda Co. put that job up to the electric companies of the country, and they could not come up to the specifications. Then Mr. Nordberg put in the compressed-air system, which gives an efficiency of somewhere upward of 50 per cent., and is giving the most absolute satisfaction, with a minimum of danger and a maximum of convenience. If we could get hold of some information as to the relative efficiencies of these electrical installations and the compressed-air system put in by Mr. Nordberg, of which there is given a full description in a recent issue of the *Bulletin*, it would be very illuminating.

William Kelly, Vulcan, Mich.—That information can be had in large part now by all who are interested. In addition to the paper by B. V. Nordberg in the *Bulletin*, there have been other papers on the subject, one by D. B. Rushmore and K. A. Pauly, presented at a meeting of the American Institute of Electrical Engineers on Mar. 11, 1910. We expect the papers now under discussion will be followed by another paper, to be presented a little later, on the results of electric hoisting at a Lake Superior mine, and when all these papers are brought

together and compared, the comparative costs by the different methods of hoisting can be arrived at quite closely.

K. A. Pauly.—I would like to ask the gentleman who mentioned the 50 per cent. efficiency for the air hoist where he obtained that figure. In the first place, I do not believe that, theoretically, such a figure is possible. In the second place, I have seen the results of the tests made at Butte, and they do not give over 29.5 per cent.; and, on top of all of that, efficiency in an air system means nothing anyway, because you have to pay for reheating the air. You have a much higher maintenance expense, both on the distributing system and the actual operating part of the equipment, the air engine.

Unquestionably the Butte system has been a complete success from an operating standpoint during the period that it has been installed, but I think that all of those who are connected with mining operations will admit that one of the most troublesome pieces of machinery about a mine is the air end of the air compressor. I think we may look for the same trouble on the engine end of the air compressor, after it has been installed some few years.

J. E. Johnson, Jr.—The figures which were published were given by Mr. Nordberg. They include the power coming in on the line to the transmission line, and the load hoisted on the shaft, which is the over-all efficiency, if there is any such thing, and these figures are about 50 per cent.

I do not know where this gentleman gets his data of 29 per cent., but I do know that papers have been published, concerning the electrification of mines and central hoisting systems using electricity, that have described travesties on good engineering. They have spent twice as much money in the installation of these systems as a compressed-air system would have cost, and have given no better result than the compressed-air system, in some cases not as good. When the gentleman says that the air end of a good air compressor will create trouble, as compared with the electric motor, I can only say that he has had an unusual experience. I have had a good deal of experience with both, and will back the air end of the air compressor to let a man sleep a good many more nights in a year than the electric motor will.

Electric Traction in Mines

BY CHARLES LEGRAND, DOUGLAS, ARIZ.

(New York Meeting, February, 1914)

In many iron, coal and copper mines where large tonnages are known before starting operation and proper provisions can be made, the problems of electric traction by trolley locomotives are not very different from those of surface plants. In such installations the gauge of the track, the radius of curves, and the clearances, both vertical and horizontal, can be made to suit the conditions of the traffic. It is more difficult to install electric traction in mines which were started with hand tramming and where no consideration was given to the possibility of mechanical traction being used. The writer having had some experience in the installation of electric traction in copper mines, the following remarks apply more particularly to these mines.

With the gauge of track usually 18 or 20 in., the weight limit of locomotives obtainable from manufacturers in this country varies from 3 to 6 tons. The full-load speed varies from 4½ to 6 miles per hour. These locomotives, being made to run on very small radius curves, have a short wheel base and a long overhang from axle to coupling, which necessitates a coupling with a good deal of lateral motion to avoid derailing the cars on sharp curves, especially if couplings are of the standard railroad automatic type.

Although 3-ton locomotives will run on 12- or 16-lb. rails, it has been found more satisfactory to use 25-lb. rails, as the track keeps in much better shape, it is easier to maintain the bonding in good order, and fewer derailments from dirt on the track occur with the larger rails. Where 6-ton locomotives are used the 25-lb. rails are satisfactory, but 40-lb. rails have proved cheaper where the traffic is heavy and the ground is soft, as the track maintenance is considerably lower with the heavy rails. The locomotives will run on 15-ft. radius curves, but on through runs it is advisable not to go below 40-ft. radius.

The voltage used should not exceed 250 to 275 volts, and the trolley wire should be protected, to prevent accidental contacts, in front of chutes and at all points where it is low. With the air lacking somewhat in oxygen and the heat and high humidity prevalent in many mines, this

voltage, which is considered perfectly safe, has proved fatal in several instances and in such mines it is advisable to have a pulmotor available and men trained to use it in case of accident.

The trolley wire should be protected from dripping water and if the water is acid it must be protected; the writer has seen instances where a very small drip has cut a No. 00 trolley wire in less than three weeks.

The track bonding should be kept in good shape. This is one of the most difficult things to do, as most of the trackmen in the mines do not realize the importance of it. A badly bonded track will increase the repairs of motors considerably, as in passing from a dead rail to a live one the sudden rush of current is liable to form an arc across the motor commutator or from the commutator to the ground.

If the locomotive is not mounted on springs it has been found advisable to put the resistance grids on springs, with flexible leads to the controller, as on small locomotives the cast metal grids are light and very easily broken.

In a mine laid out for hand tramming the grade is generally made in favor of the loaded cars (this is also done to provide drainage for the mine), so that the load is fairly uniform going down with the loaded cars and coming up with the empty cars. This gives ideal conditions for a full load on locomotives at all times; but the motors on electric locomotives are seldom made so that the locomotive can deliver its full tractive effort continuously and this ideal operating condition leads to overheating of the motors and very heavy repairs unless the number of cars attached to the locomotive is kept down to the maximum that the motors can pull without overheating. This is difficult in practice, as it seems against human nature to run a locomotive of any kind with a load that does not slip the driving wheels when starting or at every point in the track where conditions are a little unfavorable. The difficulty of getting motors of sufficient size in the small space available with 20-in. gauge has obliged us in one or two instances where traffic is heavy and continuous to build our own locomotives, putting the motors above the wheels and gearing to the axles outside of the wheels. This makes a rather cumbersome design but allows the use of larger motors and has proved satisfactory in service. Even with this design the necessary clearance in the drifts limits the weight of locomotives to about 7 tons.

Where the tonnage to be handled is not great and yet mechanical traction is advisable a storage-battery locomotive is convenient. The running expenses are not much greater than with a trolley system, depending on the conditions under which the locomotive has to operate.

The Copper Queen Mining Co. operated a 3-ton storage-battery locomotive at Bisbee for over two years, under the worst conditions of any locomotive in their mines as regards track and curvature, and the results were better than the writer anticipated. To make use of one of the

regular locomotives, the battery, consisting of 150 Edison cells, was mounted on a separate trailer. This battery had a total output capacity of 40 kw-hr., the average voltage on discharge being 180 volts. The first trays furnished to hold the cells were of the regular type for automobiles and proved to have too small a clearance between cells. The hard bumping in switching combined with very heavy sweating (due to the locomotive going from very hot portions of the mine with moisture-saturated atmosphere to colder portions near the shaft) short circuited the cells externally. After the trays were altered to provide larger clearances and the cells were painted with insulating paint there was no trouble from this source, although two or three cells were lost in a bad wreck.

The power required at power station per useful ton-mile was approximately double that required with trolley locomotives, or 1.6 kw-hr., due to extra dead weight of battery car and lower efficiency of battery compared to trolley wire and track circuit, also to the losses in the motor generator used in charging the battery. With a locomotive designed to carry batteries the difference in power would be less. The power would also have been reduced if a motor controller had been used, grouping the cells in various combinations for starting, instead of a regular controller with starting resistances.

The traffic got too heavy to be handled with this locomotive and it did not run long enough to get figures on depreciation of storage battery. The maintenance of the battery-locomotive motor was less than on the trolley locomotive, but no exact figures are available. The capacity of the battery was approximately 50 useful ton-miles on one charge.

At the mines of the Copper Queen Mining Co., in Bisbee, the power used on trolley locomotives, measured at direct-current switchboard in power station, for the year 1912 amounted to 875 watt-hours per useful ton-mile. This amount, however, includes a few lights which are connected to the trolley circuit and gives too high a figure for the locomotives alone. It applies to cars with roller bearings, about one-half of the tonnage being carried in cars of 2 tons capacity and the other half in cars of 1 ton capacity. The conditions of the cars and track have quite an important bearing on power required per ton-mile, although the writer has no accurate figures. A rough idea can be formed from the fact that on a certain track in the mine of the Moctezuma Copper Co. one 3-ton locomotive cannot pull more than five cars of 20 cu. ft. capacity, equipped with regular Anaconda axles, without slipping the wheels, while the same locomotive pulls six cars of 22 cu. ft. capacity equipped with roller-bearing axles.

For the year 1912 the cost of various items in cents per useful ton-mile at Bisbee for a total of 408,000 ton-miles was as follows:

	Cents
Locomotive maintenance	2.95
Car maintenance	1.64
Track maintenance	5.24
Trolley maintenance	3.60
Power	1.64

Locomotive maintenance includes all electrical and mechanical repairs and replacements on locomotives, as well as lubricating oil and supplies.

Car maintenance includes all repairs, oil, and supplies on cars.

Track maintenance includes all track repairs and replacements, bonding, grading, and realignment.

Trolley maintenance includes all trolley-wire repairs and replacements, and repairs to protective trough around trolley wire.

Track and trolley maintenance are very heavy, due to shifting ground.

The cost of power (1.1 kw-hr. per ton-mile) is taken at the high-tension switchboard and includes the loss in transforming the alternating current into direct current.

In comparing power used by storage-battery locomotives and trolley locomotives it would be fairer either to compare the actual input into battery with direct-current power used by trolley locomotives or use the alternating-current power input to rotary converter in both cases.

In the case of the storage battery the input was approximately 1.28 kw-hr. per ton-mile, as against 0.875 kw-hr. for the trolley locomotive.

The figures for power on storage battery are based on two days' test and therefore are not as reliable as those on trolley locomotives, which cover a year's period.

Comparison of Mining Conditions To-day with Those of 1872, in Their Relation to Federal Mineral-Land Laws

BY R. W. RAYMOND, NEW YORK, N. Y.

(New York Meeting, February, 1914)

THE situation in 1872, from the standpoint of the prospector, the locator, the possessory claimant, and the patentee of mineral land under Federal statutes, cannot be understood without a knowledge of the situation prior to 1866, and between 1866 and 1872.

The Situation before 1866

The western public domain acquired by the United States through treaties, as the result of conquest or purchase, was invaded after Marshall's re-discovery of gold in California, by an overwhelming multitude of prospectors and miners from all parts of the world. The mineral lands of the whole Pacific slope were practically unsurveyed. Congress, disgusted with the experiment of leasing mineral lands, which it had tried for 40 years, and abandoned in 1847, enacted no laws for the management of these public mineral lands, and the pioneers made their own laws governing mining titles. These local regulations applied at first to gulch-mining in the auriferous river-beds only; and they constituted a simple and practical system, adapted to the needs and means of primitive communities—significantly called "camps." They had the means of measuring distances, but not angles; they knew no property except personal property in the form of pickaxes, pans, supplies, camp-equipage, horses or mules, and mining rights. The earliest codes which they developed expressed what might be called the law of the lariat. With the lariat they measured the distance assigned to each miner along the gold-bearing gulch—a double portion to the discoverer, and a single portion to his successors, in the order of their coming. With the lariat, they hung, after such due process of law as was available, the rascal who stole a horse, or a bag of gold-dust, or a mining claim, or killed another man without giving him fair notice and a chance to defend himself. In these pioneer codes, adopted in mass-meetings and enforced by the same authority, two features concern us most:

1. They measured mining property by one dimension only. So many feet of the gulch, held by one man, meant a distance into either bank, and a distance in depth, extending as far as gold might be found.

2. Priority of right (and usually double extent of longitudinal dimension) was given to the discoverer, and, after him, to locators, in the order of location.

This system of mining titles ignored altogether the superior rights of the United States as owner of the land. As I have elsewhere shown,[1] this difficulty was solved by the common sense of the courts, which adjudicated controversies between trespassers on the public domain, according to their relative rights under local regulations, and subject to any future assertion of the higher rights of the United States.

Meanwhile, in many districts, the discovery of metal-bearing veins had inaugurated the new industry of "quartz-mining," and the pioneers simply applied to these deposits the rule already adopted for gold-bearing gulches: namely, they treated a vein as if it were a gulch; granted mining claims upon it, measured by a single dimension, and included in each claim all "dips, spurs, and angles," *i.e.*, all valuable mineral branching from the main vein between the two ends of the claim.

The Situation between 1866 *and* 1872

The Act of 1866 was an attempt to legalize the conditions which had thus grown up in the absence of Federal legislation. It declared the public mineral lands open to occupation and exploration, thus removing the guilt of trespass from prospectors and miners, and permitting for an indefinite period the exploitation of such lands, under the local regulations of the mining camps or of the States or Territories in which they were situated. This confirmed the prior right of the discoverer, which was the basis of all such local regulations. Moreover, the Act adopted the "law of the lariat," that is, the measurement of mining claims by one longitudinal dimension, and the possessory title of the locator to "dips, spurs, and angles." Finally, it provided for the purchase of permanent rights by patent from the United States, including certain rights within a given area of surface, required for mining operations on the vein located. This area was to be defined before the grant of the patent.

But unfortunately the Act of 1866 did not grant to locator or patentee any exclusive possession of the surface thus located, but only an "easement," or prior right of use. I believe that this feature of the Act, like the rest of it, was simply intended to legalize existing mining conditions, especially at Virginia City, Nev., which was in 1866 the most productive locality of "quartz-mining" in the West. The towns of Virginia City and Gold Hill were situated on and along the outcrop of what came to be known afterward as the great Comstock lode, though separate mines were then operated upon what were asserted to be separate lodes. The

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[1] Our National Resources and Our Federal Government, *Trans.*, xliv, 617 *et seq.* (1912).

valuable buildings and building-lots of these towns would have been included in any grant of the surface to the mine-owners; and the Act was so drawn as to give the mine-owners only a sort of right of eminent domain, by virtue of which they could occupy such ground as they needed for mining purposes. Whoever saw the Comstock mines of that period, must remember the amazing complex of dumps, ore-bins, roads, shaft-houses, derricks and whims, interspersed with hotels, saloons, offices, stores and residences, exhibited at Virginia City.

But in the other mining districts which were soon discovered and developed, with a sanguine enthusiasm kindled by the wonderful bonanzas of the Comstock, the mere "easement" granted to the surface of a mining location was soon found to be an unsatisfactory protection to the locator. One of the most important of these districts—and the one which, I think, had most influence in bringing about the act of 1872—was that of Reese-River, in Nevada, which was characterized by numerous sharply defined, narrow, frequently faulted fissure-veins, carrying very rich silver-ores, such as horn-silver, ruby-silver, etc. The locator upon such a vein had hard work, at best, to prove its identity in depth, beyond a fault which had cut it off, and thrown it to one side or the other. And he could not prevent other adventurers from starting shafts or tunnels in his neighborhood, and claiming as their own any bunch of rich ore that they might find. His only way to establish ownership was to push his own work underground until he reached the workings of such alleged discoverers, and then prove a practical continuity of ore from his prior location on the vein. Until that was proved, the hostile adventurers were not trespassers; they were simply exploring the public domain. And after it was proved, perhaps at great expense, he could rarely recover damages for the ore "innocently" taken by them. A writ of ejectment, expelling them from the stopes they had, perhaps, exhausted during the litigation, might be the only fruit of his victory.

This situation, promoting the practice of deliberate robbery in the immediate vicinity of every rich ore-body, was, of course, intolerable; and it is not surprising that the Federal court in Lander county, Nev., rendered a decision, so construing the Act of 1866 as to make it authorize a lode-locator to exclude prospectors from the surface of his location. John H. Boalt, the judge who made that decision, was a mining engineer as well as a lawyer, and afterward became one of the leaders of the San Francisco bar. His opinion was acute and forcible. Undoubtedly the Act ought to have meant what he construed it to mean. But his view was overruled by higher authority, though his arguments doubtless had their weight in bringing about the change inaugurated by the Act of 1872.

It is noteworthy that the Act of 1866 did not provide for placer-mining rights, or patents to placer-claims, although this was the earliest mining industry upon the public domain. The reason was that no special

difficulty had arisen as to such mining titles. The general permission to explore and occupy the public mineral lands, subject to local regulations, was enough, at that time, to satisfy that class of miners. But in 1870 an Act was passed amending and supplementing that of 1866, by providing that claims usually called placers, "including all forms of deposit except veins of quartz or other rock in place," should be subject to entry and patent. This had two important results: (1) It made placer-claims patentable, as they had not previously been; and (2) it included with placer-claims all deposits not "lodes," and included (as construed subsequently by the courts) other minerals than "gold, cinnabar, silver, or copper" specified in the original Act. There is reason to believe that both of these features, though desirable in themselves, were secured in furtherance of private enterprises—especially that of the so-called "diamond swindle," which was exposed in 1872. At least, I remember that the Act of 1870 formed part of the basis upon which this scheme was presented to New York capitalists.

The Act of 1872 was intended chiefly to remedy the above-mentioned defect in that of 1866, by granting ownership of the surface to a lode-locator. Its authors thought they were grafting a new feature upon the result of long years of growth; but they were, in fact, planting a new root altogether. The Act of 1872 was revolutionary. It made the mining right an appurtenance to the surface location, instead of granting an easement in the surface as an appurtenance of the mining right; for the reward of the discoverer it substituted the luck of the apex-possessor; and the title conveyed under it was subject to doubt and possible defeat as the consequence of new geological discoveries so long as the mining ground which it was supposed to cover might continue to be worked.

The extra-lateral right, supposed to be simply continued by the Act as a legacy from "the law of the lariat," suffered a considerable change through its dependence upon a new condition—the apex—which might or might not be correctly determinable at the time of location. This sudden introduction of a totally new basis of title led me to call the Act of 1872 "the law of the apex,"[2] a name which was universally adopted, together with that of "extra-lateral right," which I gave to the ownership of certain underground portions of a vein not vertically beneath its surface location. (The term "extra-lateral" could not have been applied under the Act of 1866, which attached no significance to the shape or position of the location as defining the mining right to which it was a mere appurtenance.) Without going into further detail as to the features of either Act, it may be said that both of them were dictated by the desire to respect as far as practicable the customs and self-made rules of miners

[2] The Law of the Apex, *Trans.*, xii, 387 (1883).

upon the public domain; and that such changes as were made were intended to meet existing conditions and satisfy the demands of influential constituencies and industries. It is impossible to explain by reference to the provisions of pre-existing European or Spanish-American codes the peculiar features of these statutes. They grew up out of local conditions, and were formulated by men ignorant of precedents and principles. Moreover, even those men were necessarily "opportunists," taking more or less blindly one step at a time. They never had a chance to frame a mineral-land law *de novo*. From the beginning, they were trying to satisfy the mining communities, and recognize as far as practicable existing local customs, remembering always that any attempt at sudden and essential change of such customs would be ridiculously futile, because incapable of effective enforcement. And of the revolutionary change which was thus made in several respects by the Act of 1872, both the authors of that measure and the communities affected by it were sublimely unconscious.

The foregoing demonstration of the "opportunist" character of Federal land legislation warrants the inquiry whether the conditions of 1872 have since been so changed as to justify new legislation in 1914.

The Situation in 1872

As I have said, the potential mischief continued in the Act of 1872 was neither foreseen nor immediately realized. The statute was welcomed in the region to which it applied as a much-needed protection to *bona fide* prospectors and their grantees, the investors of capital. No one expected it to produce a harvest of blackmail and litigation. Its immediate effect was to encourage the adventurous and speculative exploration of one new district after another; and, as the pioneer industry of mining blazed the way for the advance of all other civilized activities (though too often at ruinous cost to itself), the result was the conquest of a vast wilderness, and the creation of a new empire.

The situation in 1872 was this:

1. Indian wars had been practically removed as a serious element of danger, preventing the exploration of the public domain. Their doom was pronounced when the completion of the first transcontinental railway permitted the rapid movement of troops and supplies, so that hostile tribes could be pursued in winter campaigns.

2. Successive discoveries of rich placers or "quartz-mines" were causing excited stampedes of mining prospectors.

3. The price received for silver was such as to encourage silver-mining; and the silver-bearing deposits of such districts as the Cottonwood Cañons in Utah, White Pine and Eureka in Nevada, Owyhee in Idaho, etc., were being developed with wild enthusiasm. As we all know, certain classes of silver-bearing deposits offer outcrops of very rich min-

erals, admirably adapted to stimulate speculation. And the outcrops of silver-lead ores (already utilized in Utah, and soon to assume at Eureka, Nev., and at Leadville, Colo., immense economic importance) furnished, in their combination of lead, silver, and iron oxide, a material "smelting like butter" in the primitive furnaces of the period.

I am not here concerned with the exact dates of successive discoveries and developments in different regions, or successive advances in the mining and metallurgical industry of the West. My own public reports as U. S. Commissioner of Mining, etc., from 1868 to 1876, and many other authorities, may be consulted as to these details. What I wish to emphasize here is the character of the period just before and just after 1872, as one of new discoveries, new districts, new "processes," the exploitation of "bonanzas," and the enormous development of speculative investments in mining enterprises on the Pacific slope. It cannot be denied that the Act of 1872, with all its defects, stimulated this amazing continental development. Carlyle describes the tactics of the armies of the French Revolution as a process of "swarming"—a word which includes, in the German language from which he took it, the element of enthusiasm. The wilderness of our West was similarly overrun by the irresistible "swarming" advance of our mining pioneers, under the stimulus furnished, and in spite of the hindrances imposed (as we can now clearly recognize), by the Act of 1872.

The Present Situation

The conditions of to-day are the cumulative result of causes operating since 1872, among which the following may be named as the most important:

1. The demonetization of silver and its consequent fall in price. This naturally discouraged speculation in silver-mining, while it promoted economy in mining, handling, and reducing silver-bearing as well as other ores.

2. With the gradual exhaustion of rich bonanzas, the exploitation of large bodies of complex, low-grade ores had many important results.

a. It was both cause and effect of the improvements in the methods and machinery of mining, transportation, and metallurgy, mentioned above.

b. It employed larger numbers of men for longer periods, thereby creating greater and more permanent communities, and more numerous and varied industries, trades, and institutions. The general working of low-grade ores laid the safe foundation of civilization and progress in the new empire.

c. It brought into profitable use the baser metals, which are more essential to human industry than the so-called precious ones. Yet this development of enterprises in which gold and silver were technically

by-products really increased the production of those metals. It is both instructive and amusing to read the utterances of the prophets of the last quarter of the 19th century, concerning the future of gold and silver. Our wise predictions were nullified, not so much by the discoveries of new producing districts, as by the new experimental illustration of the old, old general truths, that the existence of a bonanza of very rich ore may, and generally does, indicate the presence of a much larger amount of low-grade stuff, which, being temporarily too poor to "pay," is either not mined at all, or rejected after mining; that the "barren ground" and the waste-dumps of one period may be the mines of the next; and that he who, by utilizing neglected constituents, or reducing costs of mining, etc., enlarges the class of "workable" ores in an old district, may have performed a service equivalent to the discovery of many new ones.

d. This wonderful advance in the exploitation of low-grade ores inevitably diminished to some extent the importance of the old-fashioned "prospector," whose business was to find outcrops, make small surface-developments, and sell out to promoters, on the basis of sample-assays. Investors no longer cared so much for "rich" assays; they wanted large masses of low grade, and a secure title, neither of which the ordinary prospector could guarantee. He became, consequently, more and more a mere scout, whose first discovery was only a call for further investigation by geologists, lawyers, practical engineers, etc., before even the promoter, to say nothing of the actual investor, would take up in earnest the proposed adventure. Moreover, the great mining concerns employed their own scouts, and the old-fashioned prospector, operating on his own account, was almost left out of the new system. He has now well-nigh passed away, as have passed many other free-lances of the vanguard of progress. We may sympathize with him, but he had to go!

3. Legal conditions likewise have been profoundly affected by industrial progress. The ore-deposits of greatest importance were very different from the comparatively narrow and well-defined gold-veins of California and silver-veins of Nevada, which the law-makers had had chiefly in view; and the provisions of the law were applied with difficulty to the great ore-bodies in the "blanket-lodes," "chambers," and "mineral-bearing zones" of Utah, Colorado, and Arizona. Vast sums were squandered in litigation before even the meaning of the terms in the statute defining the extralateral right could be fixed by the U. S. Supreme Court.[3]

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[3] Prof. John B. Clayberg, in an able paper on this subject, published in the *California Law Review*, May, 1913, and reprinted in the *Engineering and Mining Journal* of Sept. 20, 1913, expresses the opinion that the law of extralateral right is now practically settled, but adds that "many complications, now unthought of, may present themselves" in the application of the principles established in 41 years of piece-meal interpretation.

Meanwhile, the owners of large mining properties have learned to protect themselves by executing mutual quit-claim deeds or side-line agreements with neighbors, or by purchasing outright such adjoining territory as threatens future conflict of title. In fine, the volume and cost of mining litigation has been greatly reduced, though the expense and difficulty of perfecting title by patent is still too great, and the nature of such title too indefinite. This improvement in the situation, being largely due to the practical abolition of the extra-lateral right by agreements between neighbors, is an argument rather for the repeal than for the continuance of that feature of the land-laws.

Indeed, all the changes in the situation above enumerated seem to me to call for such a repeal, even at this late day. But there is a new factor which may greatly hinder that simple and obvious reform. I refer to the movement for an entirely different treatment of what are called national resources. It seems likely that any attempt to amend the law of the apex will be seized as an occasion for proposing to abolish altogether the system under which, for half a century, the public mineral as well as agricultural lands have been sold to citizens. President Taft, it is true, in a public address advocating the operation of coal-mines and water-powers under Federal leases, disclaimed the intention of altering in this respect the laws concerning other mining titles, which he said were working well enough already! But President Taft's limited outlook and moderate suggestions will not satisfy the partisans of the new "nationalism." In my recent paper, cited above, I have discussed this question, and must reserve further statements concerning it, including replies to criticisms of that paper, for another place. I mention it here simply to express my apprehension that the movement for a practicable reform may fail again, as it has failed at least twice already, through the attempt to accomplish too much. The proposal to change many provisions of the present law (to say nothing of a total change of its purpose—namely, that of transferring the public lands to citizens, and the subsequent control of them to the Territories or States in which they are situated) will have, in my judgment, as it has had already, this result: that the opponents of any one of the proposed changes will unite to oppose them all, and the friends of any one such proposed change will be divided as to some of the others, so that it will prove impossible to make a clear and simple issue, upon which the needed majority could unite. This constitutes an important factor in the consideration of the subject assigned to me by the Chairman of the Institute Committee on Mining Law, at whose request I have written this paper.

Should the Apex Law be Now Repealed?

BY CHARLES H. SHAMEL, SPRINGFIELD, ILL.

(New York Meeting, February, 1914)

I FEAR most of the Institute members are already weary of the perennial controversy about the apex law. I feel that way about it myself now, though I have been guilty of considerable contribution to the discussion in the past. The discussion does not seem to perceptibly influence previously held views and I would not again break into print on the subject but for the urgent invitation of the Chairman of our Law Committee. This energetic and able member has firmly determined to secure a revision of the mining law and among other things to eliminate the so-called apex provision from the U. S. mining statutes. He is, however, fair about it and has invited me to make "the strongest possible argument in its favor." I am suspicious that he is acting on the psychological principle that it is usually easier to convince an audience against a cause vigorously but unsuccessfully defended than against one wholly mute. Nevertheless, I realize that personally he wishes me no harm, much as he hates the apex law, and so am willing that the Institute have whatever benefit may accrue from my taking up again the unpopular side of the discussion. I say this because the attitude of a large part of our "articulate" membership seems irreconcilably hostile; their minds are made up; favorable consideration is foreclosed; and they become impatient and even sarcastic at any attempt to elucidate a favorable view of the apex law.

The exact question for discussion at the present time is not whether on abstract, or any other considerations, the apex law is the best possible rule, but the very different proposition whether, after nearly 50 years of statutory life and much longer as a practically universal miners' custom, it is now just and expedient to repeal the apex law.

At this point it seems to me that we may profitably devote a paragraph or two to the subject of the origin of law in general, as we are presumed to be considering the subject from the high viewpoint of the general welfare of the nation. The most comprehensive and accurate definition of law in the legal sense is, that *it is the body of rules for the regulation of human conduct which is enforced by the State,* that is, by the nation.[1] Legal

[1] Carter: *Law, Its Origin,* etc., p. 14.
Dillon: *Laws and Jurisprudence of England and America,* p. 5.

writers have proposed several theories of the origin of law, such as the "Divine Lawgiver" theory; the "Law of Nature" theory; the "Contract" theory (of Rousseau), etc.; but most present writers on the subject maintain that custom is the primary source of almost all law. Thus Mr. Carter, long one of the leaders of the New York bar, says:

"The prime requisite of human society, that without which it cannot subsist, is that each member should know what to expect in the conduct of others, and that fair expectations should not be disappointed. When he knows this, and only when he knows it, he knows how to act himself. This requirement is supplied by conformity to custom. . . . Custom, therefore, is the only law we discover at the beginning of society, or of society when it is first exposed to our observation."

James Bryce, perhaps the ablest writer on English and American constitutional law, says:

"There is, to be sure, a school of juridical writers which does not admit that the people do or can thus make Law, insisting that custom is not Law till the State has in some way expressly recognized it as such. But this view springs from a theory so incompatible with the facts in their natural sense, that a false and unreal color must be put upon these facts in order to make them fall in with it. . . . the ancient doctrine, both of the Romans and of our own forefathers—a doctrine never, till recently disputed—held the contrary."[2]

Such being the origin of law in general, we are justified in assuming that any law which grew out of a custom—whose legislative or judicial formulation was only the crystallization of previously existent general usage—is the nearest possible expression of the will of the people on that subject. It is of legitimate birth, and is not to be lightly dispossessed of power without conclusive evidence that the conditions and circumstances causing its generation and fostering its growth to the maturity of statutory enactment have materially altered or entirely disappeared. No law can be satisfactory in operation—no law will stand long which is opposed to the will of the people, and in this connection the will of the people of the mining States is the will of the whole people. Let us apply these criteria to our mining law, and to the apex provision thereof, in particular.

Beyond all question, the whole of the U. S. mining law, including the apex provision, was founded on customs which had prevailed universally for many years in the precious-metal mining regions of the United States—ever since this industry began at the discovery of gold in California. The testimony on this point is conclusive. Justice Field, one of the ablest members of the U. S. Supreme Court, who had lived in California during its early days, says:

"Into these mountains the emigrants in vast numbers penetrated, occupying the ravines, gulches and canyons, and probing the earth in all directions for the precious metals. . . . In every district which they occupied they framed certain rules for

[2] Bryce: *Studies in History and Jurisprudence*, p. 671.

their government by which the extent of the ground they could severally hold for mining was designated, their possessory right to such ground secured and enforced, and contests between them either avoided or determined."[3]

Senator Stewart, who had himself taken no insignificant part in the great gold rush of '49, says:

"Upon the discovery of gold in 1848 a large emigration of young men immediately rushed to that modern Ophir. These people, numbering in a few months hundreds of thousands, on arriving at their future home found no laws governing the possession and occupation of mines but the common law of right which Americans alone are educated to administer. They were forced by the very necessity of the case to make laws for themselves. The reason and justice of the laws they formed challenge the admiration of all who investigate them. Each mining district in an area extending over an area of not less than fifty thousand square miles, formed its own rules and adopted its own customs. The similarity of these rules and customs was so great as to attain all the beneficial results of well-digested general laws."[4]

Also Yale, the earliest American writer on mining law, says of the origin of the law and its benefits:

"They reflect the matured wisdom of the practical miners of past ages, and have their foundations, as has been stated, in certain natural laws, easily applied to different situations, and were propagated in the California mines by those who had a practical and traditional knowledge of them in their varied form in the countries of their origin, and were adopted, and no doubt gradually improved and judiciously modified by the Americans."[5]

In the light of such evidence the contrary statements made by some opponents of the apex law are unworthy of consideration, such as:

"Begotten in bland self-complacence by a group of opulent mechanics," and

"What ineffable wisdom is displayed by a government which permits the perpetuation upon its statute books of a law resulting from the nebulous perplexities of a council of day-laborers and village chiefs regarding the occurrence of ore deposits! . . . Are we in America—I ask it in all seriousness—to remain forever the victims of the deification of the peasant and the mechanic, the hewer of wood and the drawer of water? Are we to continue to accept as truth and rules of conduct the ephemeral ravings of an enriched, illiterate proletariat? What is the law of extralateral rights but the misbegotten conception of untutored laborers assisted by provincial pettifoggers, who set at defiance, and banish from consideration, alike the physical and chemical principles controlling the deposition of ores, and the precedent of centuries of the world's previous mining experiences?"[6]

The apex law, then, having originated in well-settled, universal custom of the mining regions; having been approved at its embodiment in statute law by the sense of right and justice of the ablest men in Congress and among the miners; having been, after six years of trial, re-enacted in a strengthened form without protest, was unquestionably as perfectly

[3] Jennison vs. Kirk, 98 U. S., 453.

[4] *Congressional Globe,* 1st Session, 39th Congress, p. 3225.

[5] Quoted in Lindley on Mines, 2d ed., sec. 42.

[6] Chester W. Purington: *Engineering and Mining Journal,* vol. lxxix, No. 13, p. 622 (Mar. 30, 1905).

adapted to then existing conditions as any human law could be. But there has arisen in later years among the speech-making, periodical-contributing mining men considerable outcry against the apex law. The first question, then, is whether mining and geological conditions have altered to such an extent that the originally wholly satisfactory apex law is no longer adapted to promote the best interests of the mining industry. Unless such a change in conditions has occurred, the alteration of the law to the diametrically opposite policy will be contrary to the clearly manifested and duly enacted will of the people and productive of dissatisfaction, confusion, and injustice.

Of course geological conditions have not changed. They are now and will continue in the future the same as they were 50 years ago. Our knowledge of geological conditions has increased, it is true; but it remains to be seen whether this is a justification for the repeal of the apex law. A very great change has, however, occurred in the financial conditions of mining; and in this I believe we may discover the secret source of the expressed dissatisfaction with the law. In early days, mining was largely carried on by the men who searched out and discovered the ore deposit, or by those who had made fortunes in other mining ventures. Now it is largely controlled by the great financial groups and conducted according to the trust and monopoly methods. Mining has become one of the assets of "Big Business." The complaint against the apex law comes chiefly from this new factor in mining affairs, and its employees and sympathizers. In my own experience among prospectors and such of them as had graduated into mine operators, I do not remember to have heard even one man favor the repeal of the apex law. It is also noteworthy that among the minority who, according to the recently published series of opinions collected by our Law Committee's Chairman, are opposed to the repeal of the apex law are found most of the State bureau officials, and others who presumably reflect the feelings of the actual miner.

The foregoing sociological and juristic considerations, and the opinions of the part of our population actually doing the work of mining and prospecting, are of the utmost importance, and should prevail against the opinions of individuals and of comparatively small bodies of specialists largely employed by "Big Business."

But the case for the apex law does not rest alone on such general considerations; and I now pass to a review of its concrete advantages and alleged disadvantages. I can be brief here; for the field has been explored many times already by rival partisans, and its main features—its veins of pay ore and its barren dikes—are known to all of us. The essential feature of the apex law is, that it permits the claim owner having the apex of a vein, lode, or ledge to follow such deposit between certain legally determined vertical planes to any distance, even if he thereby, on a dipping deposit, passes beyond vertical planes through his boundaries.

In its favor, it is urged that in plain justice and economic expediency, when a miner has discovered and by his work developed a dipping vein, and worked it on the incline to the vertical plane through his boundary, he should not be stopped by this wholly artificial obstacle, and see another without labor and without price reap the advantage of his discovery and development. Besides its injustice, this would be economically inexpedient; for it would require much more expenditure in dead-work to extract the ore body through two or more shafts than through one. The matter is so plain that amplification and argument are unnecessary. Out of its recognition by practical miners grew the custom which was in due time enacted into statutory law, as I have already shown historically. Unless some disadvantages can be proved against the apex law sufficient to outweigh these considerations, it would be unjust and inexpedient to abrogate this principle and set up the contrary one. Let us therefore examine the disadvantages which are alleged to outweigh the benefits of the law. It is claimed that while the law is "beautiful" in theory, it is in practice "immeasurably bad" because of the difficulty of determining the legal apex, and therefore the ownership of a given ore body; and that by reason of this difficulty an immense amount of tedious, costly and unnecessary litigation has occurred in the past and is likely to occur in the future. The whole case against the apex law rests on these allegations—difficulty of identification and consequent excessive litigation.

Let us first see whether the assertion that the law causes excessive litigation is well-founded. But let us also remember that no law, human or divine, is immune from violation. Are not the fundamental precepts of the ten commandments often broken? A law can only be condemned on this ground when it causes distinctly more litigation than other similar laws. The charge of causing excessive litigation has been brought against the apex law so often that to most persons outside of the legal profession mining litigation is practically synonymous with apex law litigation. If the most unfounded statement is reiterated frequently and forcibly enough, the average person will at last accept it as true. It occurred to me, while considering this subject, to examine the mining decisions themselves, and ascertain whether, in fact, an undue proportion of such suits arose out of the apex provision. For this purpose, I took the series of decisions collected in Morrison's *Mining Reports*, comprised in 22 volumes, issued from 1883 to 1906. These contain all of the American mining decisions of any importance up to the latter date.[7]

I considered that the most accurate way of arriving at the proportion

[7] I did not include the volume recently issued (1912), by the same publishers, beginning a new series, because its plan has been enlarged to include also irrigation and drainage cases and I did not have time to separate the latter from the mining decisions.

of apex litigation was to count the total number of syllabuses of all the legal questions contained in all the decisions and compare this with the total number of syllabuses referring to the apex law.[8]

Of course not all mining litigation was carried to the higher courts; but this was a new question for the courts. The apex section itself was brief and indefinite; so that at least an equal, probably a much larger, number of mining cases involving the apex provision were appealed than those involving other provisions. It was during this period, also, that all the important deficiencies of the apex law were supplied by the principles evolved by the courts to make it more definite; so that the proportion of apex litigation is not likely to be underestimated by this method, but rather the contrary.

I confess that I was surprised at the actual figures. The total number of syllabuses in the 22 volumes of decisions is 5,808, of which the number concerning the apex law is 115. The apex cases are only about 1.9 per cent. of the whole.[9]

The apex provision is one of the 28 sections of the U. S. Mining Code as it appears in the Revised Statutes. It occupies 20 lines and the whole code 341; that is to say, the apex section, being longer than the average, constitutes 5.8 per cent. of the whole. Therefore the terrible apex provision causes less than one-third in proportion to its length of the litigation that the other provisions of the mining code do. Instead of causing 99.9 per cent. of mining litigation, as Dr. Raymond has somewhere stated, it has really caused much less than its proportionate share of the trouble. Facts are stubborn things. The chief, the constantly reiterated, the convincing argument against the apex law is based on a gross mistake as to the facts in the case.

But, some one may say, how could so many men be mistaken for many years about the matter? It is another psychological phenomenon not hard to understand, when examined into attentively, without convicting any one of willful falsehood. The persons making these statements so often that they finally came to be accepted as the truth of the matter,

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[8] For the benefit of those who are unacquainted with the law reports, which are the repositories of the largest part of existing law in the American and English legal systems, I would say that the text of each decision is nowadays always preceded by an abstract stating briefly the actual different legal propositions decided in the case, arranged in paragraphs, one to each proposition. This is termed the syllabus. Morrison, the editor of the series, is the author of Morrison's *Mining Rights*, well known to all mining men. This is a guarantee that these syllabuses were made or passed upon by some one understanding the mining law and that all the legal propositions contained in the decisions are properly represented in the syllabuses.

[9] I did not have time to check over the count a second time to be sure of absolute accuracy, but the totals under each heading assembled in the digest of the syllabuses appended to each volume were added on a computing machine; and I am confident that the figures given are substantially correct.

were not lawyers, familiar with the decisions themselves, but engineers and others familiar with the scientific side. Their attention was strongly attracted to the litigation involving the apex law because this turned on geological and scientific facts with which they were familiar. These were the cases reported and discussed in the scientific and mining periodicals. Even when known, the numerous lawsuits turning on other provisions of the law, having little meaning or interest, soon faded from memory and were forgotten, leaving only the clear recollection of the apex litigation standing out from the whole mass of mining litigation, which was dimly realized to be enormous in the aggregate. Further, it was chiefly in the apex litigation scientific men were called in as expert witnesses. The great bulk of mining litigation was carried on without them, and so attracted little attention from them. In this connection also, do not forget that there has always, in all ages and in all lands, been proportionately more litigation in mining than in other industries. As I have said in another place:[10] "The truth is, that from the very nature of the industry of mining for the precious metals, involving more than most others the element of chance—awarding to some rich prizes and to others bitter disappointments only—it is peculiarly subject to bitterly fought litigation. This has been the case in all countries and all times. It long ago attracted the attention of the King of Spain, who, in 1785, in promulgating new mining ordinances for Peru, said:

> "The King, convinced of the deteriorated condition in which the important branch of mining of that kingdom has fallen, from a want of method in governing the Reales of mines, *and also on account of the frequent and troublesome litigations* in which the individuals of this useful profession are involved, causing them enormous expense and distraction from their business by requiring them to reside in the capital and other places where they go in the prosecution of their lawsuits, etc."[11]

There is nothing in the annals of apex litigation which can equal the litigation lasting in one form or another nearly 50 years about the zinc deposits at Franklin Furnace, N. J., which arose under the identical common law principle of ownership within vertical planes contended for so strenuously by the opponents of the apex law.[12]

The above considerations, I believe, largely account for the prevalence among engineers of a belief in the existence of excessive apex litigation, but with some there are other less creditable factors operating. One of these is jealousy of the legal profession. Several examples of this attitude cropped out in the recent symposium "Should Our Mining Laws Be Changed," appearing in the *Mining and Engineering World* during the past summer. For instance: "I think that principle was put

[10] Shamel: *Mining, Mineral, and Geological Law*, p. 272[10].

[11] Halleck on Mines, p. 589.

[12] Any one interested can find this remarkable litigation described with citations to the original decisions in my book, *Mining, Mineral and Geological Law*, p. 41, *et seq.*

in the United States law for the benefit of the lawyers rather than for anyone else";[13] and "Our mining laws appear to benefit the lawyers more than the people in general, or anyone else. . . . extralateral rights benefit lawyers only";[14] and "I believe it was originally implanted in that law with the idea of creating strife. . . and business for certain classes of professional men."[15]

As to the probable amount of future litigation liable to arise from the apex law (which is the only question worthy of practical consideration), it should be remembered that during the period of over 40 years that has elapsed since its enactment, its admitted indefiniteness and deficiencies have been almost completely corrected by the decisions of the courts, and there is little likelihood of any notable number of new questions in this connection coming up in the future. I frankly admit that this was not the cheapest or the easiest way of supplying the necessary details; but it has at last been measurably accomplished in that way; and if we now think we can see how this could have been done less expensively, that is no valid reason for rejecting the so costly results, and adopting the contrary policy. I do not deny that there may exist theoretical possibilities of a few new situations arising under the apex law; but I believe the possibility of any important amount of litigation arising on new points is very remote, and wholly insufficient to overcome the weighty considerations against repeal.

An additional exceedingly important consideration against *now* repealing the apex law is that as to all claims already located it would still be in full force and effect. It could very readily happen that a subsequent locator whose own rights were limited by vertical boundary planes would nevertheless be compelled to yield extra-lateral rights within his boundaries to a prior locator. In fact, the repeal *now* of the apex law would tend to further complicate legal rights and inevitably provoke additional litigation, instead of accomplishing its suppression. Outside of Alaska, the jurisdiction of the apex law has been so thoroughly prospected that there is little hope that any important new mining districts will hereafter be discovered; and a change of legal rights in existing districts would unquestionably produce more instead of fewer disputes. These are the strongest considerations which occur to me against the repeal of the apex law at the present date, and, together with other facts detailed above, irresistibly lead me to believe that it would be fundamentally unjust, economically inexpedient and contrary to the best interests of all occupied in mining, except possibly the trusts and monopolies and their satellites,

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[13] Warren D. Smith: *Mining and Engineering World*, vol. xxxix, No. 4, p. 159 (July 26, 1913).

[14] Murray Innes: *idem*, vol. xxxix, No. 1, p. 22 (July 5, 1913).

[15] E. E. Olcott: *idem*, vol. xxxix, No. 3, p. 112 (July 19, 1913).

for Congress at this late date in the development of our mineral resources to change the law by eliminating the apex provision therefrom.

With some reluctance, for fear of possibly causing new complications and consequently more litigation, I venture, however, to propose a revision and modification of the apex law, as follows:

1. A restatement of the apex section giving full details for its application to all the different situations of veins or other deposits, boundaries, etc., that have arisen in the past or that may be reasonably likely to arise in the future. This should be based on a careful comparison and codification of the decisions of the courts applied to the different situations. If thus based on existing decisions of the courts, it ought not to cause any increase in litigation, and would enable miners to determine their rights for themselves, and proceed according to law, when the different situations arise in practice. They cannot themselves dig out this information from the court decisions, or even know where to find these. This plan of more definite formulation of the apex law was indorsed by nearly all of those who favored its retention, in the symposium mentioned above.

2. The addition of as complete and accurate definitions as are afforded by the resources of modern economic geology, of the specific kinds of ore bodies to which the apex law should be declared to apply. Merely as a suggestion and a basis for discussion, I would include true fissure veins, shear zones, contact deposits, volcanic necks, and possibly replacement deposits in limestone, as these forms are defined by our former president, Professor Kemp, in his *Treatise on Ore Deposits*, p. 56.

3. As of still greater importance than the matter of definition, I would make the enjoyment of extra-lateral rights to any subsequently located claim depend on the results of an examination by competent, impartial scientific authorities, instead of a battle of alleged experts in a law court before a jury.[16]

4. As a basis for discussion, I would suggest that this scientific authority be the U. S. Geological Survey, which would determine, upon application of the owner, after due notice to adjacent claim owners, whether a given ore body was one to which, by the proposed definitions, extra-lateral rights legally belonged or not. There should be provision for an appeal under fixed conditions, not to a court, but to a board of higher officials of the Survey, or to some other board of competent and impartial authorities —their decision to be final, and not subject to review by the courts in any manner. Under this plan, the parallel end-line requirement could well be omitted, and the parallel limiting planes for extra-lateral excavation fixed

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[16] I would observe in passing that it seems that much of the disfavor felt by reasonable engineers toward the apex law grows out of their disgust at the performances of many alleged experts during lawsuits involving geological matters. The plan I propose would entirely eliminate this source of honest dissatisfaction, and put the purchasable expert out of business.

also by the Geological Survey. This would entirely prevent any litigation about apex questions on claims located hereafter, and at the same time would preserve the justice and all the benefits of the present apex provision. This geological survey should be paid for by the claim owner, and should be allowed to serve as the patent survey, so that expense to the claim owner would not be greater than under the present system.

Discussion

R. W. Raymond, New York, N.Y.—I wish to thank Mr. Shamel for his vigorous presentation of that side of the question before us, on which, if one should judge from the contributions here presented, he stands alone. For, in the first place, he does not in fact stand alone, but is backed by a host of citizens in the States affected by the "apex law," who have often exhibited heretofore their opposition to its repeal by the pressure they have brought to bear upon their Congressmen, some of whom have been retired to private life, apparently as a penalty for supporting that reform. Moreover, many intelligent and public-spirited persons have ably supported his view in other publications than our *Transactions;* and I may say without discourtesy that the most complete refutal of Mr. Shamel's argument would leave other and stronger presentations of his case yet to be considered. But if he did stand alone, he would still be not only entitled, but cordially welcome, to a hearing here; and, after any amount of discussion, from which he emerged as victor or victim, he would be warranted in demanding that the Institute should not, by any official act or expression, commit itself to either side of this or any other question. For by its immemorial tradition, as well as its former and its present Constitution, the Institute is a forum for discussion, and not a tribunal for adjudication.

As is well known, I have been for many years an earnest opponent of the principle of the apex law. And I cannot but be pleased to find that my professional colleagues and fellow-members so generally approve the views on that subject which I have so frequently expressed since my first paper was presented at the Troy meeting, in 1883.[17] Yet I would not have the Institute transcend its proper sphere by formally advocating even this reform, so dear to me, and, in my judgment, so important to the mining industry. With this explanation I shall proceed to offer a reply to some of the statements contained in Mr. Shamel's paper.

Mr. Shamel's excellent elementary statement as to the foundation of law in custom, no one will care to dispute. But in his hands it is a boomerang; for the apex provision of the Act of 1872 was a monstrous violation of all known customs. The customary initiation of mining

[17] The Law of the Apex, *Trans.*, xii, 387 (1883–84). See also my subsequent papers: The Law of the Apex, Appendix, *Trans.*, xii, 677 (1883–84); Lode-locations, *Trans.*, xv, 272 (1886–87); End-lines and Side-lines in the U. S. Mining Law, *Trans.*, xvii, 787 (1888–89); Imaginary Boundaries, *Trans.*, xviii, 182 (1889–90).

titles was discovery. Nobody had dreamed of granting to a prospector mining rights upon a vein which he had not discovered—especially upon a vein which somebody else had discovered. And the covering of an undiscovered "apex" with a claim located for the convenient working of another and altogether separate vein, had never been dreamed of as a legitimate basis of title against a real discoverer, who had developed the vein by shaft or tunnel. Nobody had ever heard of an "apex." The dictionaries said it was a point; the statute said it was a "top;" the courts finally declared it to be an edge, and then defined this edge as a surface. But the custom of miners, which Mr. Shamel regards as the sacred foundation of law, had nothing to say about it. Upon this absolute vacuum the apex was builded. Mr. Shamel's eloquent assertion of the merits and the due reward of the prospector and discoverer condemns this fanciful and unprecedented invention of a new structure of law, of which the base was "the apex." Mr. Shamel cannot produce from ancient or modern history —even from his own treatise on *Mining, Mineral and Geological Law*—a custom, sacred or profane, which warrants this absurdity.

Even the present extra-lateral right, which is commonly regarded as simply continued from the Act of 1866, as that was simply a confirmation of pre-established custom, was in fact entirely novel and arbitrary, not only in its relations to the apex, but also in its relations to all surface ownership. For the earlier right was not properly "extra-lateral" at all, since the boundaries of the surface location did not affect it, and indeed the surface location conveyed no exclusive possession. What the Act of 1866 really granted was a certain length of the lode, and by implication the right to mine upon it to indefinite depth. The lines of the surface location did not condition this right. But the Act of 1872 grants no definite length of lode, and limits all underground rights by such conditions as the course of the apex and the position of the surface boundaries of the claim may at any time be shown to require. And as to those parts of the vein or veins apexing within the location upon which a valid extra-lateral right is granted, that right does not cover actual mining, unless it can be done wholly inside of the vein itself, without cross-cuts, stations, or even niches for supplies, or notches for timbers, excavated in the country rock, no portion of which is included in the extra-lateral possession granted. Mr. Winchell's paper, presented at this session, gives illustrations of this feature of the statute. I cannot say it is unprecedented; for there are amusing cases in the English law books, in which the mineral under a certain area has been sold by the surface owner without the right to break the surface by making roads, shafts, dumps, etc., and it has been held that the purchaser of the mineral owned it, but could not legally get at it or extract it, against the wish of his grantor, the surface owner. To guard against such a situation, our private mining leases usually contain express provisions for roads, dumps, mines, machinery, etc.; and it is

universally held that the permission to mine and carry away minerals covers all necessary disturbance or excavation of country rock under the surface.

I do not suspect Mr. Shamel of consciously approving the foregoing violations of custom and equity by the law of the apex. His own argument condemns them.

Mr. Shamel disputes the assertion that the apex provision of this law has caused an enormous and disproportionate amount of litigation, on the strength of an ingenious statistical research which he has made, with the aid of an adding-machine, in twenty-two volumes of Morrison's *Mining Reports*.

Before I proceed to consider this remarkable investigation, let me note that, in this connection, Mr. Shamel quotes me as having "somewhere stated" that the apex provision has caused "99.9 per cent. of mining litigation." I have not been able to trace this vague reference far enough to ascertain what was the statement of mine to which it alludes; but I have found the place which Mr. Shamel regards as his authority, namely, a letter in the *Engineering and Mining Journal*, the writer of which ascribes to me the statement that "the 'extra-lateral' underlies 99.9 per cent. of our mining litigation," and says that in the San Juan region of Colorado the proportion is the other way, "at least, so far as the number of cases is concerned"—the overwhelming majority being "adverse" suits, to say nothing of other suits over grub-stakes, division of interests, trusteeships, etc. This passage is given, without its context, in Shamel's *Mining, Mineral and Geological Law*, p. 273. I need only say, with regard to it, that I do not regard all litigation among miners as "mining litigation." Contests concerning advances of capital, tools or materials, on promise of participation in the profits of an adventure, are not peculiar to mining, though the advance may be called a "grub-stake." Nor are contests over the division of interests, trusteeships, etc., mining litigation, though they may concern property in mines or ores. But the "adverse" suits, said to constitute in San Juan the overwhelming majority, are fights over the priority or validity of possessory titles to surface locations, carrying extra-lateral mining rights which are limited by the surface lines. These prospective rights invariably underlie such conflicts. For the grant of the United States is not definite, but conditional and uncertain; and the surrender by a locator of a portion of his surface area, otherwise worthless, may lose for him a yet undiscovered "apex," with unknown possibilities in depth, or, by changing his surface lines, may abridge his rights upon the "discovery" vein over the apex of which (known, but not yet fully traced throughout the claim) he has made his location. This is the reason that "adverse" suits are so frequent and so bitter with regard to mining claims. I must conclude that the correspondent of the *Journal* confined his account of lawsuits

"underlain by the extra-lateral" to those in which the nature and limits of that right were the questions at issue, excluding those in which the right itself was in whole or part the object or the cause of controversy. I think Mr. Shamel has fallen into the same error.

He declares himself to have been surprised at the result of his investigation. It is the method, not the result, which surprises me. He sorts 5,808 cases contained in Morrison's *Reports* into two classes, those in which the prefatory syllabus mentions apex rights, and those in which it does not. And he finds only 115 in the first class, and 5,693 in the second. Whereupon he declares that the apex cases are only about 1.9 per cent. of the whole, and that the chief argument against the apex law " is based on a gross mistake as to the facts in the case." Mr. Shamel suggests a psychological explanation of the error, avoiding the necessity of charging the authors with "willful falsehood." But, while grateful for his good will, I prefer another explanation, equally protecting my honor, and not impugning my common sense. The amount of mining litigation due to the apex law is not measured by the number of leading cases in which questions of apex rights are directly decided, but by the time, money, and labor expended on lawsuits under this mining law, by reason of its apex rights. The argument which Mr. Shamel controverts is based on the injury to the mining industry wrought in this respect by the law; and that injury consists in the uncertainty of mining titles, which involves constant risk of litigation, and the nature of the litigation thus caused, which makes it ruinously expensive—including, as it often does, costly underground dead work, interfering with productive operation; the preparation of special maps, sections, and models; and the work of experts for long periods, as well as the costs of the long trials themselves.

Lawyers are well aware that a court will not decide a point of law not properly before it in the case under trial. This principle has been illustrated over and over again in the U. S. Supreme Court, by the decision of a case on some point of procedure, which rendered it unnecessary to pass upon the weightier questions at issue. It follows that numerous cases, supposed to involve the construction of the apex law, and carried up to the U. S. Supreme Court for the purpose of obtaining such a construction, were sent back to be tried again, because of defects which settled the controversy anyhow, without solving the more difficult problems presented. The report of such a case would say in its syllabus nothing about the apex law, though the case itself would never have existed at all, or would never have been carried so far, but for that peculiar law.

Again, many cases really caused by the apex provision, go up, even to the U. S. Supreme Court, on interlocutory proceedings. Several of the suits of the Montana Mining Co. described in Mr. Goodale's paper,[18] as

[18] The Apex Law in the Drumlummon Controversy, this volume, p. 328.

well as others, which he has omitted to mention, belong in this category; and I could add to the number from my own experience.

Moreover, a large number of litigated controversies concern operations in what might be called the extra-lateral region, though they do not involve the construction of the extra-lateral right. These cases are chargeable to the apex law, because they could not possibly have arisen without it. In every such case, no matter what legal question is involved, the parties must show their respective titles, and the apex is immediately an issue, though it may not appear in the syllabus.

Still more important is the circumstance that the vast majority of mining cases decided in the State, or Federal district, courts do not get to the U. S. Supreme Court. A very few decisions of that tribunal have controlled the opinions of the courts below, in innumerable instances. The same is true of the decisions of the State Supreme Courts. Consequently, the leading cases selected by Morrison as authoritative in the construction of the apex law furnish no measure, even of the number (to say nothing of the importance and cost) of the contests caused by that law.

Mr. Shamel reminds us that all laws—even the Ten Commandments —can be violated. The obvious reply is, that the Decalogue can be easily understood, while the apex law cannot; and that the principal victims of the latter are those who have conscientiously tried to obey it. Mr. Goodale's paper, already cited, tells but one story out of many, which go to explain the present reluctance of capitalists to invest in mining property carrying the incubus of this law, under which no title is safe against attack based on "new developments," or new geological theories.

Mr. Shamel adduces the famous litigation over the New Jersey zinc mines as a sample of what might take place under a law not granting extra-lateral rights. Since he describes this case at length in his book, he must be aware that it originated in the granting of two mining leases on the same land—one for franklinite and iron ores, and the other for zinc and other ores—and that the only mining question involved in it was the distinction between these substances—the minerals themselves being mixed in the deposits mined. But the litigation was prolonged for 50 years by the appearance of new parties, disputes over intermediate conveyances, and other controversies which had nothing to do with mining law. The protracted war ended in a compromise between the grantees of the parties long dead; but there was no time during its existence when the construction of the law involved either the least difficulty or the least advantage to either party. Under any law, men may make ambiguous contracts, and their grantees may fight, if they see fit, over the interpretation thereof. It is the peculiarity of the apex law, that it grants without definition, and leaves its grantee open to attack forever. Besides,

the New Jersey case is unique, whereas the attacks upon the *bona fide* purchasers of the U. S. mineral lands are innumerable.[19]

But Mr. Shamel, while opposing the repeal of the apex law, modestly proposes a few amendments of it, which would be as revolutionary as anything he deprecates. He would have the apex section "re-stated," so as to contain the results of careful comparison and codification of the decisions of the courts, and give full details for their application " to all the different situations of veins or other deposits, boundaries, etc., that have arisen in the past or that may be reasonably likely to arise in the future." This, he thinks, "would enable miners to determine their rights for themselves."

But this is only the beginning. The law should also contain geological definitions of the specific kinds of deposits to which it applies. These should be as complete and accurate as the resources of modern economic geology afford. Of course, Mr. Shamel, being a lawyer, knows that if the law authorizes the conveyance of extra-lateral right in certain classes of deposits in place, and not in certain other classes, then the conveyance, by patent, of such rights upon a given deposit, supposed to belong to the former class, would be absolutely void, as an unauthorized act of the Executive, if the deposit should be shown, at any subsequent time, to belong to the other class. No matter how many years of undisputed possession might have elapsed; the grant having been void at the beginning, the grantee would be liable to ejectment from his extra-lateral ground, and to damages for the trespass. This danger exists in the present law. But Mr. Shamel' s amendment would make it more acute and more complicated. I notice that he includes "volcanic necks" among the classes to which he would have the law apply. But he does not say how the course of the apex of a volcanic neck is to be determined.

A further recommendation of Mr. Shamel, which he thinks still more important, is that "the enjoyment of extra-lateral rights to any subsequently located claim" shall " depend on the results of an examination by competent, impartial scientific authorities, instead of a battle of alleged experts in a law court before a jury."

I do not exactly understand the force of "subsequently located" in this statement. Under the present law, the rights of junior locators are already subordinated explicitly to those of senior locators; and the

[19] In his discussion of Mr. Winchell's paper, which I have seen while writing out these remarks for publication, Mr. Shamel presents, as another instance of prolonged litigation, the prosecution of Freeman, Hawthorne and others for criminal misuse of the U. S. post office in the promotion of vulgar mining swindles. I do not see the pertinency of this illustration. The ease with which fraudulent enterprises can be promoted by circulars, offering stock, is notorious. It is estimated that $100,000,000 has been extracted from credulous investors by that method. Time and money are well spent in prosecuting such criminals, and we do not call the prosecution unnecessary "litigation."

majority of disputes about mining titles originate in claims on the part of the senior locator to extra-lateral rights which he asserts and his opponents deny. In every such controversy, one party is *prima facie* the senior, and the other the junior, locator. Does Mr. Shamel propose that the senior locator shall have whatever he claims, while an impartial scientific board shall determine, not only whether the junior locator has a good defense, but whether he has any extra-lateral rights at all? Moreover, under the present law, in a controversy over apex rights, the junior locator may have, and always professes to have, the apex covering the ground in dispute. If he is right, then he is really the senior locator on that particular apex; that question of fact would have to be determined before the impartial scientific board could act at all; and when it was determined, there would be no need of the board.

After careful study, I reached the conclusion that Mr. Shamel meant simply the substitution, in the trial of "extra-lateral" controversies, of an impartial board, instead of experts paid by the respective parties, with the further difference that the decision of this board should be binding upon judges and juries, and reviewable only by a higher board of the same character—"not a court." This proposition is at least conceivable and debatable, though it involves the overthrow of the present principles of our jurisprudence, the denial of the right of a citizen to appeal for justice to the courts of his country, the conferment of judicial authority upon officials neither elected by the people nor appointed with primary reference to their ability to construe or administer the law. In the administration of justice, such boards may advise, but the courts must decide.

But on reading further, we find that Mr. Shamel proposes his scientific board, not to settle controversies but to prevent them. His plan is, that a claim owner, after due notice to adjacent claim owners, shall apply to the U. S. Geological Survey (or some other scientific authority) to determine whether a given ore body shown in this ground "was one to which, by the proposed definitions, extra-lateral rights belonged or not;" that is to say, whether it did or did not belong among the classes—"veins, shear zones, contact deposits, volcanic necks, and possibly replacement deposits in limestone"—to copy Mr. Shamel's list. But the essential thing is not merely the character of the deposit, but the possession of the apex, to what extent and in what direction. Apparently, Mr. Shamel's board is to settle these points also, quietly disregarding the "parallel end-line requirement," and fixing end planes according to its own judgment. But the law grants extra-lateral rights on all other apexes within the location. If the owner finds another vein in his ground, must he call for the impartial board again, and get it to fix a new pair of end planes? Above all, are these "impartial" (that is to say, *ex parte*) decisions of the board to stand forever, in spite of all later developments of the facts?

Without further discussion of these propositions, I must say in conclusion that I think they constitute a very strong argument against Mr. Shamel's main position; for a law that needs, in the opinion of its advocates, such radical and revolutionary violations of sacred custom, constitutional principle, American liberty and administrative efficiency to make it perfect, had better be repealed than thus amended.

E. W. Parker, Washington, D. C.—In two important instances in this country the law of the apex was done away with by consent of the parties. At Bisbee, and in one place out in Michigan, the two parties agreed to abolish the apex law, and by mutual consent took the vertical side line and other vertical lines as the delimitation of their properties. That worked out very satisfactorily.

Senator Thomas J. Walsh, Helena, Mont.—Inasmuch as the Drumlummon litigation has been mentioned here, I would like to make a statement, as it may not be known to all present, that that litigation outlived three generations of lawyers. The distinguished member of the Institute who has just addressed you was associated with the first generation, and I was in at the death.

It is to be borne in mind, and this I speak with entire deference, that the views of lawyers as well as of engineers, concerning the wisdom of the continuation of the present apex law, carrying with it the extra-lateral right, are likely to be formed or colored by the success or failure of their own efforts in causes in which it played a part.

I have glanced hastily over Mr. Goodale's paper, and I have no doubt it is characterized by the good temper and judicial spirit he usually displays. But it must be borne in mind that Mr. Goodale was an expert in that case, and he was on the losing side. I merely suggest that in reading the paper of Mr. Goodale, you will bear in mind that you are reading a statement of an advocate of one side of the litigation. I do not mean to say it is inaccurate. In looking it over it seemed to me that facts which seemed to us of very great consequence were not incorporated. However, I would not be misunderstood about this, and I do not understand that there is any contention that the final result of the Drumlummon case, the Nine Hour case, was colored with any injustice except so far as injustice inheres in the law which was applied to the case. I am myself convinced that the apex law should be abolished. That as a matter of fact it does give rise to interminable and very expensive litigation, is generally recognized.

Two ideas suggested by Dr. Raymond may, I think, be urged in very just criticism of the paper read in support of the extra-lateral right.

The Amalgamated-Heinze litigation was, as everybody knows, based almost exclusively on contentions concerning the apex right; and yet that litigation developed practically no law at all upon apex rights. The law

had practically all been settled. It involved largely questions of fact under the law as it had been settled, questions of practice and procedure, and of substantive right other than such as had that foundation.

I have no doubt you could go through the reports of that litigation, which was continued for 10 years, and I would undertake to say you cannot find half a dozen syllabuses referring to any question under the apex provision. And yet the entire field of litigation almost was traversed. For instance, in that litigation we developed all the law applicable to the writ of supervisory control in our Supreme Court. Writs of prohibition, writs of mandamus, and to proceedings for contempt. And yet the whole litigation rested on the assertion of apex rights.

Rossiter W. Raymond.—Wasn't there a very important interlocutory matter in the Drumlummon case not reported by Mr. Goodale, and which was most extraordinary, where they made a survey of the mine before a suit was brought?

Senator Walsh.—Yes, sir. That went to the Supreme Court of the United States. It involved a statute in our State which permits examination of a property involved as well as of adjacent property, preparatory to the suit. Proceedings were instituted under that statute for the purpose of ascertaining the facts, and the constitutionality of that statute was attacked. The St. Louis Co. sought to go down into the workings of the Montana claim through the workings made by the Montana Co. The Montana Co. attacked that statute as being in violation of its constitutional rights. We finally went to the Supreme Court of the United States, which held that the statute was a proper legislative act. The order for inspection had been granted, and, the inspection having been made, a suit was instituted. Then after the suit was instituted there was a question of the equity powers for permitting an investigation or examination. The adverse was set up, and that resulted in a compromise whereby the strip was conveyed by the owners of the St. Louis to the Nine Hour, and the adverse was dismissed in pursuance of the stipulation.

Then the conveyance was refused, and an action of specific performance was instituted for the purpose of compelling the conveyance; and we had a lot of law on specific performance, and under what circumstances that must be enforced.

Now that was another line. Then, when the conveyance was eventually had, the question became important as to what apex rights were obtained by reason of the peculiar provision of the instrument of conveyance, and when the case was tried out upon the ordinary law of apex controversies, it went to the Supreme Court of the United States, which held that by virtue of the peculiar language and provisions of that deed of conveyance, the rules of law applied by the lower court were not correct; and the case was reversed and sent back for another trial.

Now, there was no question of apex right at all. That is to say, the law applicable to apex rights was considered settled. So that nobody upon the merest reflection should be bound to adopt the conclusion that the amount of litigation is to be determined by the number of propositions upon the question of apex rights.

Next, it is suggested in the conclusions arrived at by Mr. Shamel that the apex law should be more clearly defined, with the aid of all the adjudications made by the courts under varying and conflicting conditions during the past 40 years, and when so defined, and its boundaries fairly well fixed, litigation will to a large extent disappear. I think that is entirely impracticable. The fact about that matter is that we are confronted with exactly the same difficulty in legislation concerning amendments to the Sherman Anti-trust law. It is claimed by many people that now it is possible to fix definitely by bounds the things which would constitute a violation of that law. But the trouble lies in the new methods of arriving at the results which were intended to be obviated by that law; and as a result many practices which should be condemned will escape and be considered legitimate. So it is a rather difficult kind of a task to attempt to elaborate the definition of the apex and eliminate litigation in the future. Indeed, I would be afraid that course would give rise to no end of litigation. Every provision, every clause, would then become the subject of renewed litigation, and the question would arise whether by reason of the peculiar language it was intended to abandon some of the principles which had been theretofore abandoned as being unjust. So, I think you would breed rather than obviate litigation by any such provision.

Then, Mr. President, I do not think the suggestion that these questions should be transferred from the courts to the Department of the Interior could ever have been suggested by any man who knows the temper of the Western people, who are most interested in this matter. Indeed, we have always maintained that the best feature of our mining law is that which throws into the local courts conflicts arising between conflicting interests, rather than have the crude methods pursued in the Land Office and other departments of the government applied to the decision of such matters.

And I undertake to say that unless the whole law is changed it will be impossible to compel the litigant to abandon his rights in court and trust them to the arbitrament of even the distinguished gentlemen at the head of the Geological Survey. I do not know why anybody should want to transfer a controversy between me and my neighbor, if a controversy should arise between us, in respect to the apex of a vein—why the determination of that controversy should be transferred from the vicinity where it arises, into some government bureau in the city of Washington. Nor do I understand why it should be determined there, rather than be-

fore a judge out in the mining country who has made it a duty to be advised concerning mining law and mining business; and tried before a jury that has imbibed more or less mining law knowledge by reason of long residence in the vicinity where such questions are constantly arising.

I do not mean at all by anything said in the beginning that I do not agree with the conclusions at which Mr. Goodale arrives, that perhaps this is the time for the abolition of the apex law.

Charles H. Shamel (communication to the Secretary*).—I have been favored by the Secretary with a copy of the stenographic report of the discussion relating to my paper on the apex law. This report, however, is plainly so defective that I can only be sure of the general drift of the remarks of the speakers. Dr. Raymond is mistaken in thinking my paper especially directed at his former utterances. My argument was based on the origin of law in general from custom and the undesirability of reversing legal rules founded on custom. Dr. Raymond says that the apex law, instead of being founded on previous custom, was absolutely revolutionary in character. As nearly as I can understand him from said report, he bases this assertion on the alleged fact that before 1872 no one had ever heard of the "apex;" nobody knew what it meant. This is a mere play on the mathematical definition of the word. The fundamental principle of the so-called apex law—that is, the right of the discoverer to follow a dipping vein wherever it might go without regard to surface boundary lines—had been known and practiced generally in the precious-metal mining districts of the United States ever since such mining began after the great California gold discoveries of '49. This is proved beyond any doubt by the quotations I gave in my article and by the collection of the local district rules and regulations previous to 1872 made by Clarence King for the 10th census.

Because, in the law of 1872, the word "apex" was used in a statute for possibly the first time in an effort to render the principle definite and precise does not render the principle new. Such argument is mere verbal dialectic and indicates there is nothing more substantial to offer against this argument for the apex law

I submit that the position is still unshaken that the apex law, being founded on previous general customs of the precious-metal-mining districts (to which alone it applies), should not be abrogated and the contrary rule adopted. It is not maintained that conditions have materially altered except perhaps by the entry of "Big Business" into the mining industry. No one has ever suggested that the prospectors and mine operators originating from them are not practically unanimous in favor of the apex law. These are the "people;" they are the repre-

* Received Apr. 3, 1914.

sentatives of the nation in relation to the mining industry; their customs alone originate law, their wishes should control the provisions of the statute.

There is no merit in the objection that the number of apex syllabuses does not represent the proportion of apex litigation. The apex question was just as often subordinate in cases chiefly contested on other sections of the mining laws as such other questions were subordinate in cases turning chiefly on the apex provision. In modern times these syllabuses form a very carefully prepared and accurate abstract of everything in a court decision, with a separate paragraph for each contested question or point in the case. There is no better way than this practicable to estimate the relative amounts of litigation regarding different legal questions. Wherever the apex law was involved in a decision it appears in the syllabuses. This method is infinitely more trustworthy than the mere impressions of any man, however experienced he may be, for such impressions are formed only by each individual's personal experiences, which are wholly accidental with reference to the whole field of mining litigation. The confused and erroneous ideas so widely prevailing concerning the apex law are well illustrated by the member who, in the discussion, referred to it as in force in Michigan. That State was never, at any time, subject thereto. The statement that the U. S. Supreme Court evades deciding the main questions in cases is another striking illustration of the desperate straits of the opponents of the apex law and of the lack of valid argument against it. I am still satisfied that counting the syllabuses is as fair and accurate a way as can be devised for determining the proportion of apex litigation and that, in truth and in fact, the apex section of the mining statute has caused less than its proportionate share of mining litigation and therefore should not be abrogated on account of causing excessive litigation.

What I proposed as to a new way of granting apex rights and possibly of deciding some apex controversies was merely a suggestion for starting discussion. I am not, however, convinced by what the able and experienced Senator from Montana has said that some such plan would not be an improvement over the present method. Also I did not mean to suggest that such grant or contest should be made at or conducted in Washington, D. C., but, on the contrary, would provide that the hearings be had in the locality, with an inspection of the property by the board of experts.

I have always recognized that there were difficulties in the administration of the apex law, but these exist in relation to the other and unattacked provisions of the mining law in even greater degree, as the facts I have adduced seem to me to prove conclusively. These facts have not been disproved or explained away by anything in this discussion. The law is just in principle. Therefore I still maintain that it would be economically inexpedient and ethically unjust now to repeal the apex law.

The Apex Law in the Drumlummon Controversy

BY CHARLES W. GOODALE, BUTTE, MONT.

(New York Meeting, February, 1914)

THE principles and theory on which the U. S. mining law of 1872 was based are well understood, and have been discussed at great length by many writers. The papers by Dr. R. W. Raymond[1] in the *Transactions* of the American Institute of Mining Engineers have covered the subject very fully, with explanations of practical results in many adjudicated cases. It is believed that the following instance of the application of the law in recent years will have some weight in a discussion of proposed changes in our mining laws.

The litigation between the St. Louis Mining & Milling Co., and the Montana Mining Co., Ltd., a British corporation, over portions of the Drumlummon lode covered more than 20 years, and resulted in a judgment for damages in favor of the St. Louis Co. of such an amount that the Montana Co. declined to pay the judgment, and therefore lost the entire property.

The Drumlummon lode claim in the Marysville district, Mont., was located in 1876 by Thomas Cruse. When he staked out his claim, he assumed that the discovery on the Drumlummon vein, and another showing of mineral about 200 ft. distant, were on the same vein, and the center line of the claim was given a course of N. $57\frac{1}{2}°$ E. Development of the Drumlummon vein soon showed that its strike was about N. 15° E., and that the other outcrop was on the North Star lode; so it was inevitable that the Drumlummon vein would cross one or both side lines of the location, and the Montana Co. found it advisable to acquire adjoining claims on both sides of the Drumlummon, in order to avoid possible litigation over apex rights. They bought the Marble Heart, but would not purchase the Hopeful (see Figs. 1 and 2), at the terms proposed for the reason that exploration in the Cruse level had shown the vein to be barren in that region. The owners of the Hopeful were sinking an incline from that claim in 1889, and the Montana Co. enjoined them, contending

[1] The Law of the Apex, *Trans.*, xii, 387 (1883–84).
The Law of the Apex, Appendix, *Trans.*, xii, 677 (1883–84).
Lode-locations, *Trans.*, xv, 272 (1886–87).
End-lines and Side-lines in the U. S. Mining Law, *Trans.*, xvii, 787 (1888–89).
Imaginary Boundaries, *Trans.*, xviii, 182 (1889–90).

that owing to the triangular form of their location, they had no extra-lateral rights. When the cause was heard by Judge Knowles in the U. S. District Court in Helena in June, 1890, he supported the contention of the plaintiff, and no appeal was taken, because it was found that the

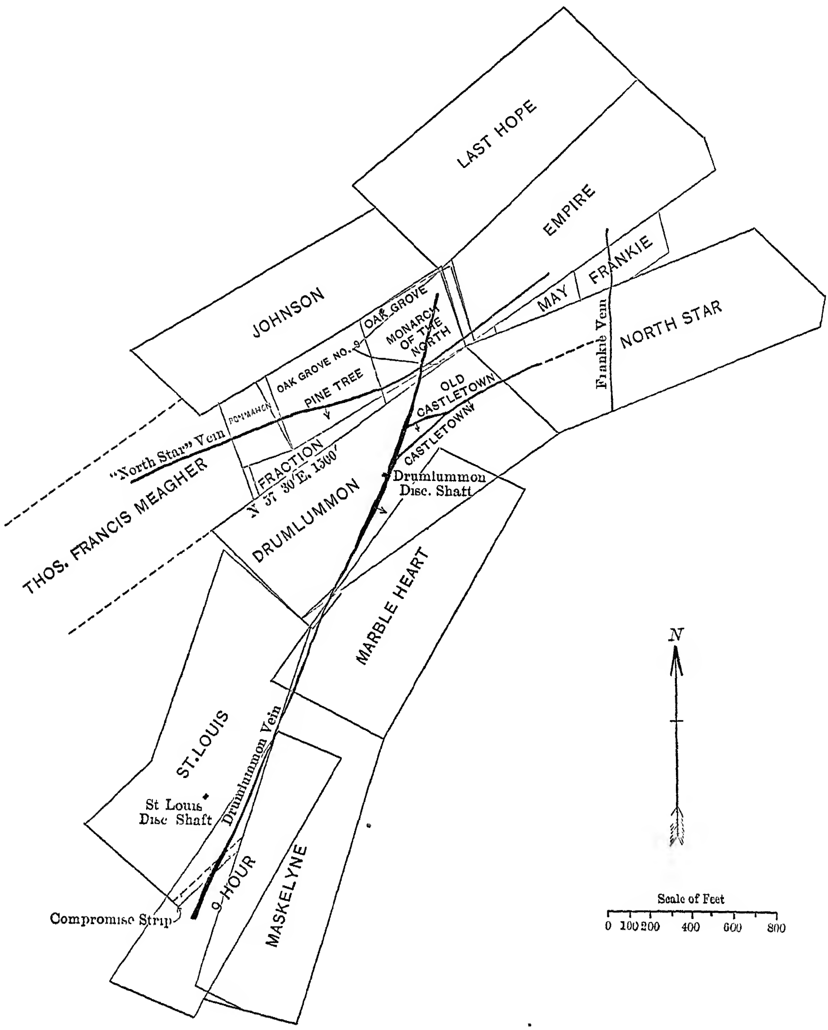

FIG. 1.—THE DRUMLUMMON AND SURROUNDING LODE CLAIMS.

portion of the Drumlummon vein in controversy was not of sufficient value to justify further litigation.

Before passing to other matters connected with the litigation an incident of the Hopeful fight will be related. When the shaft had reached a depth of nearly 250 ft., the owners drilled deeper holes than usual in the bottom, and charged them heavily with powder, believing

that they were so near to the Cruse level that the holes when blasted would make an opening into that level. Before firing, they ran up the American flag as a signal to all the world that they had the English company "dead to rights," and would soon prove the extent of its trespass. They heard the shots go off, but as no smoke came up, one of them went down to investigate. Hearing nothing from him, another went down, found the first man overcome by powder fumes, got him into the bucket, and after getting in himself, signaled to hoist. Before the bucket reached the surface, he also became unconscious, and what was expected to be a triumph, came near being a tragedy. It was fortunate that the flag did not have to be lowered to half-mast.

The St. Louis claim was located Sept. 28, 1878, as an extension of the Drumlummon. There is abundant evidence from the location notice, and from other facts, that its side lines were straight, as shown by dotted lines on Fig. 2; but the discovery vein of the St. Louis proved disappointing when opened, and, the 9-Hour location having been made in the meantime by William Robinson, July 26, 1880, on a promising discovery of ore, the St. Louis owners, in surveying their claim for patent in July, 1881, ran their lines so as to take in the 9-Hour discovery. When Robinson objected, they made angles in their side lines, leaving out the shaft, but by such a narrow margin (about 10 ft.), that when they applied for patent, he put in an adverse claim. On the 7th of March, 1884, he was induced to withdraw his suit, the St. Louis owners agreeing to convey to him, on the issuance of their patent, a portion of the ground described as follows:

"Commencing at a point from which the center of the discovery shaft of the Nine-Hour lode bears south 39 degrees 32 minutes east, said course being at right angles to the boundary line of the St. Louis lode, between corners 2 and 3, fifty feet distant, thence north 50 degrees 28 minutes east on a line parallel to the aforesaid boundary line of the St. Louis lode claim, between corners 2 and 3, 226 feet to a point on the boundary line of the St. Louis lode between corners 1 and 2; thence south 20 degrees 28 minutes west along said boundary between corners 1 and 2, 60.5 feet to corner No. 2 of St. Louis lode; thence 400.31 feet to corner No. 3 of St. Louis lode; thence north 46 degrees 10 minutes west along the line of boundary of St. Louis lode, between corners 3 and 4, 30 feet to a point; thence north 50 degrees 28 minutes east along a line parallel to the boundary line of St. Louis lode, between corners 2 and 3, 230 feet to the point of beginning, including an area of about 12,844.50 square feet *together with all mineral therein contained.*"

As this would have the effect of moving the St. Louis line 40 ft. farther away from his discovery, he felt secure in his mineral rights to the 9-Hour vein. The territory covered by this contract was known through all the years of subsequent litigation as the "Compromise Strip." (See Fig. 2.) The locator had only developed the property to a limited extent, when he sold it to the Montana Co.

Going back now to the beginning of the litigation with the St. Louis M. & M. Co.—a suit was started on Oct. 14, 1890, by that company

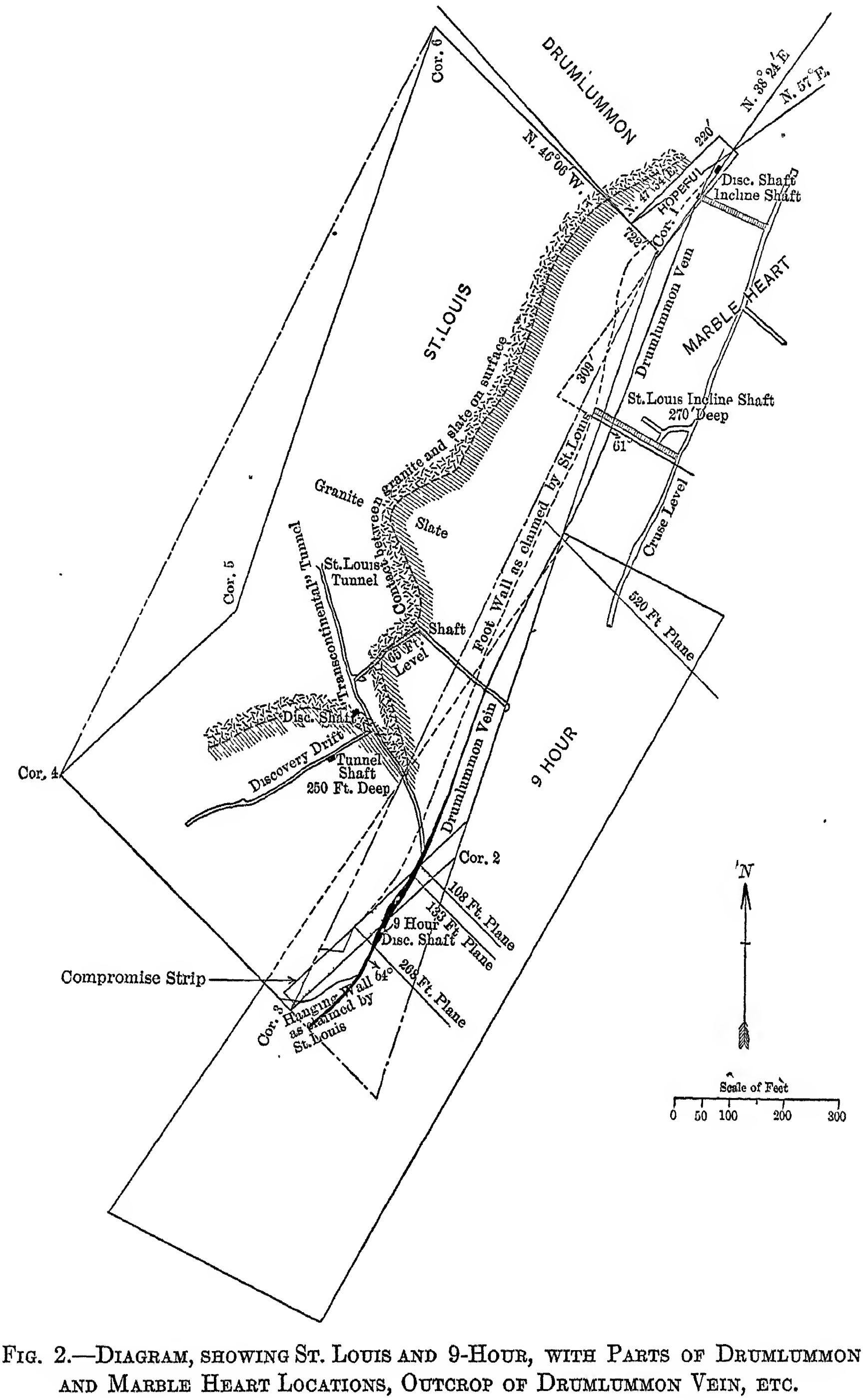

Fig. 2.—Diagram, showing St. Louis and 9-Hour, with Parts of Drumlummon and Marble Heart Locations, Outcrop of Drumlummon Vein, etc.

against the Montana Co. for trespass and $2,000,000 damages. An incline shaft had been sunk on the St. Louis claim to a depth of about 370 ft. (Fig. 2), in an effort to find the Montana Co.'s workings, as it was known that the Cruse level had been driven several hundred feet south of the Drumlummon end line, and into the Marble Heart claim. This shaft was started as close as possible to the side line of the St. Louis, and made parallel to the known dip of the Drumlummon vein. The geologists of the plaintiff asserted that it was sunk on the foot-wall of the Drumlummon vein, which, they said, entered the St. Louis claim at its north end line with a width of about 70 ft., varying from that to about 30 ft. on its course southerly; and they claimed the Jubilee and Jubilee No. 2 ore shoots in virtue of apex rights to which they were entitled by the alleged fact that they had the foot-wall in the St. Louis claim, the hanging-wall being in a junior location, the Marble Heart. The case came on for trial April 17, 1893, in the U. S. District Court in Helena, and five weeks later, the jury gave a verdict in favor of the defendant, thus supporting its geologists in their statement that the Drumlummon in its apex through the region in question was a narrow vein, not exceeding 3 ft. in width, existing between two well-defined walls and with a distinctive barren filling. The nature of this vein matter is shown below, where also will be found a partial analysis of the country slate or hornstone, both *within* the wide vein as claimed by the plaintiff's geologists (A), and *outside* of it (B).

	Barren Vein Matter 1 ft. to 3 ft. wide Per cent.	(A) Foot-wall Hornstone Per cent.	(B) Hanging-wall Hornstone Per cent.
SiO_2	23.	58.2	62.5
FeO	2.7	3.4	3.4
CaO	33.7	7.9	5.2
MgO	5 2	1.8	2.3
Al_2O_3	4.6	18.0	18.5

It will be seen there is very little difference in the composition of the two samples of hornstone; but the plaintiff insisted that what the defendant called the whole vein, was only the hanging-wall gouge, and that the rock between this and the plaintiff's alleged foot-wall, from 30 to 70 ft. distant, was "broken, brecciated, recemented vein matter." The defendant pointed to many places where the stratification planes of the slate were strongly in evidence, and asserted that wherever they were indistinct this condition could be explained by their proximity to the contact with diorite.

The plaintiff was undoubtedly influenced in his exaggerated claim for $2,000,000 by the name, "The Jubilee," given to the ore shoot in

controversy by the defendant. The name might have implied that the ore was of extraordinary richness, but it was in fact based upon the incident that it was discovered June 21, 1887, the day when all Englishmen were celebrating the Golden Jubilee of Queen Victoria, the fiftieth anniversary of her accession to the throne.

A second suit, based upon the same facts as in the case just mentioned, but covering a later period, was dropped.

And now we come to another chapter of the war between the two companies, the battle ground being shifted to the extreme south end of the mine. (See Fig. 3.)

After the purchase of the 9-Hour claim, the Montana Co. began active exploration of the ground both in the discovery shaft and in deep levels. By the summer of 1893 developments had shown that the vein would cross the east side line of the St. Louis claim as patented; and on June 19, 1893, the St. Louis Co. commenced an action to restrain the Montana Co. from working any part of the vein, the apex of which was in the St. Louis claim as patented, and for $10,000 damages, for ore extracted within the boundaries of the compromise ground. A temporary order was issued, restraining the Montana Co. from sinking its apex shaft upon the compromise ground near the boundary between that ground and the 9-Hour claim. The case was removed to the Federal Court, where a new complaint was filed Sept. 16, 1893, claiming $200,000 damages for the ore then extracted. For 100 ft. or more along the surface, and to a depth of about 50 ft., the ore was richer than had been found in any other workings of the Drumlummon vein; and the fight for its possession became very bitter. The Montana Co. claimed the ground in controversy by virtue of the agreement to convey the compromise ground. The action being in the Federal Court, it could not maintain its right without the full legal title to the ground, and thereupon it commenced an action to compel the St. Louis Co. to deed to it the compromise ground, in accordance with the agreement which had been entered into with Robinson and his associates. Pending the proceedings in this "specific-performance suit," the proceedings in the Federal Court were suspended. The specific-performance suit dragged its length along until the year 1898, when the Supreme Court of the United States affirmed the decision of the State District and Supreme Courts, requiring the St. Louis Co. to convey the compromise ground in accordance with its agreement, which was done, and a deed was executed July 1, 1898, embodying the description as hereinbefore set forth.

The patent of the St. Louis claim was issued in July, 1887, and William Robinson, or his successor in interest, the Montana Co., should have received a deed promptly, but it was only given after eleven years of annoying and expensive litigation.

In November, 1898, the St. Louis Co. filed its first amended complaint

in the United States Circuit Court, claiming the right to the ores *beneath the compromise ground* by virtue of its ownership of the apex of the vein within the limits of the St. Louis claim, wholly outside of the compromise ground, from a point on the east side line of the St. Louis claim between corners Nos. 1 and 2, 520 ft. distant from corner No. 1 of the St. Louis claim to a point on the west side line of the compromise strip distant 108 ft. from the intersection of the west side line of the compromise ground with

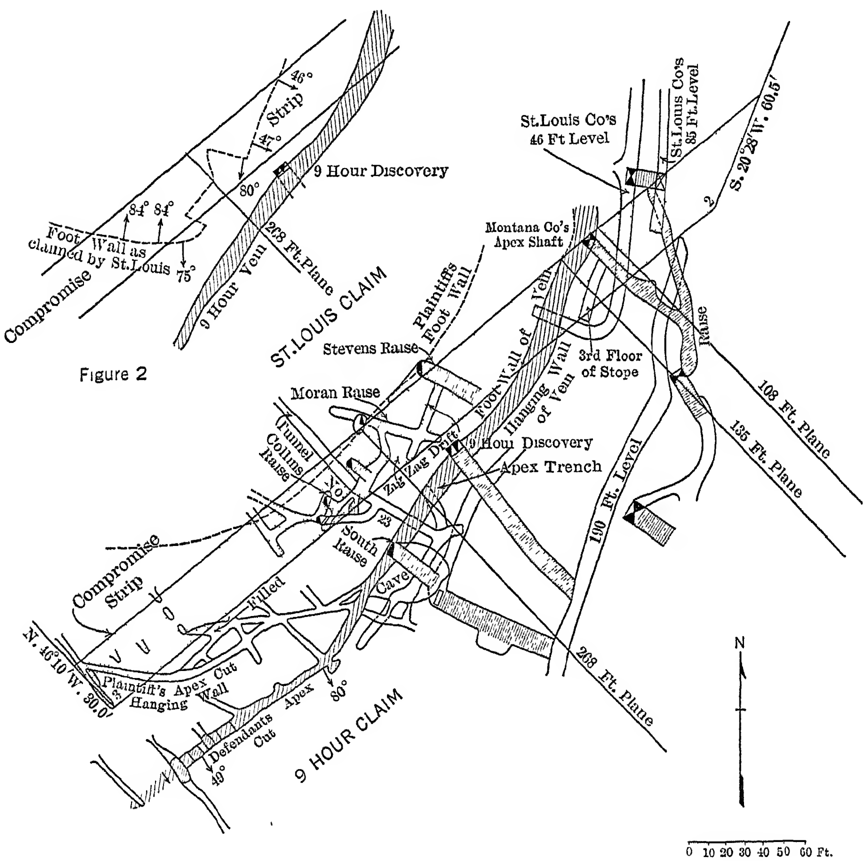

FIG. 3.—WORKINGS IN ST. LOUIS AND 9-HOUR LOCATIONS.

the east side line of the St. Louis claim, running from corners Nos. 1 and 2, where the hanging-wall of the vein began to cross from the St. Louis ground into the compromise ground, and for an additional portion of the said vein for a distance of 25 feet to the point where the foot-wall of the vein passed out of the east side line of the St. Louis lode claim into the compromise ground. These points of departure of the hanging-wall and

foot-wall from the St. Louis ground into the compromise ground became known as the 108-ft. and the 133-ft. planes.

The case was not reached for trial until 1899. On June 24, 1899, shortly before the commencement of the trial, the plaintiff amended its complaint, alleging that since the filing of the original complaint and up to and including the time of the filing of the second amended complaint, the defendant had extracted an additional amount of ore of the value of \$400,000, making the total damages claimed \$600,000. The trial was had before Judge Knowles in the U. S. Circuit Court in August, 1899, and resulted in a verdict for the plaintiff in the sum of \$23,209 for ore extracted north of the 108-ft. plane, or from a vein which had its apex entirely within the St. Louis claim outside of the compromise ground. The District Judge held that in order to entitle the plaintiff to recover it must have within its own surface lines the entire apex of the vein from which the ore was extracted. Both parties sued out writs of error, the St. Louis Co. upon the ground that it was entitled to the ore within the vein to the extent that it had any of the apex within its surface lines, and the Montana Co. on the ground that the deed conveyed to it all of the mineral beneath the compromise ground, and that as the verdict embraced damages only for ores extracted from beneath the compromise ground, it was entitled to a judgment. The Circuit Court of Appeals reversed the case on the St. Louis Co.'s writ of error, holding that that company, as the owner of the senior location, was entitled to recover to the extent that it had any of the apex within the surface of its ground, and affirmed the judgment to the extent of \$23,209, overruling the Montana Co.'s contention that the deed conveyed the ore beneath the compromise ground, where such ore was found in a vein apexing partly or wholly outside of the deeded ground. This action of the Court of Appeals was reversed by the Supreme Court of the United States on writs of error sued out by the Montana Co.; and that court held that the reversal of the judgment of the Circuit Court as to one portion of the case reversed the entire case, and remanded the case to the Circuit Court for a new trial, without deciding any of the points in controversy.

The case was again tried in the Circuit Court in Helena, before Judge Hunt, District Judge, sitting as a Circuit Judge, in May and June, 1905. Judge Hunt, following the ruling of the Circuit Court of Appeals, held that the plaintiff was entitled to recover for the ores extracted between the 520-ft. and the 133-ft. planes, and a verdict was rendered in the sum of \$195,000. Writs of error were again sued out, and the case was reviewed by the Circuit Court of Appeals. It then went to the Supreme Court of the United States, which, on Jan. 14, 1907 (204 U. S. 204), rendered its opinion that the deed to the compromise ground conveyed all of the mineral beneath the compromise ground. As the decision of that point might end the litigation, none of the other questions were directly passed upon.

But in his opinion, Mr. Justice Brewer raised, for the first time, the suggestion that the deed to the compromise ground carved out a section from the vein.

When the mandate was filed in the Circuit Court, the Montana Co. moved to dissolve the injunction, which had been granted at the time of filing the original complaint, restraining it from extracting ores beneath the compromise ground, basing its motion upon the decision of the Supreme Court of the United States that the deed to the compromise ground conveyed to the Montana Co. all of the ores beneath its surface. On March 30, 1907, Judge Hunt, District Judge, sitting as a Circuit Judge, granted the defendant's motion and dissolved the injunction. The St. Louis Co. then applied to the Supreme Court of the United States for a modification or an explanation of its opinion relative to the construction of the deed, but the Supreme Court denied the application, without any further opinion. The St. Louis Co. then, on Aug. 28, 1907, made an application for leave to amend its complaint, so as to claim damages for ores extracted from the vein on its dip after it had passed through the compromise ground, placing its damages at $500,000 for ores extracted from that portion of the vein on or about the 30th day of June, 1893, and for $500,000 for ores extracted from that portion of the vein between June 30, 1893, and the date of tendering this amended complaint. It also alleged that the foot-wall of the vein was at all points either in the compromise strip or the St. Louis claim, and passed out at some indefinite point across the south end line of the St. Louis claim as patented; the contention of counsel for the St. Louis Co. being that under the Supreme Court decision, the St. Louis Co. owned all ore in the vein after it had departed from the compromise ground on its dip, so long as any part of the apex of the vein lay within either the compromise strip or the St. Louis claim.

This proposed amended complaint not only extended the surface area in which was embraced the apex of the vein from which the ore was alleged to have been extracted, but carried the place of trespass into the depth of the mine and into stopes from which, many years before the filing of this amended complaint, ore had been taken, assumed by the complainant to be of the same high value as that taken from the compromise ground near the surface. The proposed amended complaint also set forth the fact that the Montana Co. had worked out the remaining veins belonging to it, had ceased its operations in Montana, and was in an insolvent condition, having no property within the jurisdiction of the Court, except the practically dismantled mining plant. The plaintiff asked for an injunction on the equity side of the court, restraining the Montana Co. from mining upon the compromise ground, notwithstanding the decision of the Supreme Court of the United States that the ore beneath that ground belonged to the Montana Co., basing its right to an injunction

upon the allegation of insolvency and inability of the Montana Co. to respond in damages in the event that the St. Louis Co. recovered judgment; and that the St. Louis Co. must necessarily recover judgment in some amount, because the portion of the vein from which the ores had been extracted was, by the decision of the Supreme Court, awarded to the St. Louis Co.

This construction of the decision of the Supreme Court was assailed by the attorneys for the Montana Co. upon the ground that the declaration of Mr. Justice Brewer in the opinion of the Supreme Court, that the effect of the compromise deed was to carve out a section of the vein, leaving the remaining portion unconveyed, referred only to the portion of the vein on its dip where all or a part of its apex lay within the St. Louis claim, and had no reference to the vein after its apex had wholly passed into the compromise strip, and that the Supreme Court by its refusal to modify or amend its mandate had practically so determined. Objection was also made to the filing of this amended complaint upon the ground that by removing the point of departure of the foot-wall from the 133-ft. plane to the south end line of the St. Louis claim, there was brought into the litigation a trespass upon an area of ground not embraced in the original ground, and that, as to that portion of the damages claimed, the statute of limitations had barred recovery. These contentions were finally overruled by the Circuit Court, and on Dec. 2, 1907, leave was given to file the third amended complaint. The defendant answered; and on Jan. 10, 1908, Judge Hunt issued an injunction restraining the Montana Co. from extracting ores from beneath the compromise strip pending the litigation. This injunction was unique in the history of mining litigation in Montana, in that it restrained the Montana Co. from extracting ores from the portion of the ground awarded to it, in order that these ores might be preserved to answer any judgment which might be recovered against the Montana Co. for trespass upon the portion of the vein which, it was claimed, the Supreme Court had awarded to the St. Louis Co. An appeal to review this action of Judge Hunt was taken to the Circuit Court of Appeals for the Ninth Circuit, and on March 2, 1909, the action of the Circuit Court was affirmed.

The case then came on for trial again before Judge Hunt in 1909, commencing June 14 and ending August 11. Before and during the trial, extensive explorations were made upon the surface ground, and the case was bitterly contested by the experts of the two parties as to the location of the foot-wall. At the close of the testimony on behalf of the Montana Co., the St. Louis Co. amended its third amended and supplemental complaint and replication, by withdrawing the allegation of the compromise ground as a part of the St. Louis claim, and substituting in lieu thereof the allegation, contained in the former complaints, that the compromise ground was and always had been a part of the 9-Hour claim. The com-

plaint was further amended by alleging that the apex of the vein in controversy passed entirely into the compromise ground at the point designated as the 268.6-ft. plane. This amendment, which was strenuously objected to by counsel for defendant, and was made after the granting of a sweeping injunction upon the construction of the Supreme Court decision, urged by the St. Louis Co.'s counsel, and after defendant had been compelled to prepare its defense of the cause to meet such legal theory, and after all of the evidence in chief of the St. Louis Co. had been introduced upon this theory—permitted the St. Louis Co. to make a complete somersault in its legal position, and seek a recovery upon new allegations of fact, upon which it confessedly could not have recovered under the complaint as it stood up to the time when the Montana Co. was required to present its evidence. Under the pleadings as they stood up to this time, a portion of the apex of all the vein in controversy lay within the compromise strip, and the compromise strip "was and always had been a part of the *St. Louis* claim," which part had been conveyed to the predecessors of the Montana Co. by a conveyance prior to that by which the remainder of the St. Louis claim had been conveyed by the same grantors to the St. Louis Co. Under the law the effect of the first deed—that conveying the compromise strip—was to convey all of the vein on its dip so long as any part of the apex lay within the compromise strip. By this last amendment, the St. Louis Co. was permitted to take the position that the compromise strip "was and always had been a part of the 9-*Hour* claim," thus presenting a question of rights on the dip of a vein, the apex of which was divided between the junior 9-Hour claim and the prior St. Louis location, thereby presenting entirely different questions both of law and fact. By this last amendment, the controversy was narrowed down to the question, whether the foot-wall passed into the compromise ground at the 133-ft. plane or at a point farther south, designated as the 268-ft. plane. The jury found that the foot-wall entered the compromise ground at the 133-ft. plane (as contended by the witnesses of the Montana Co., who maintained that the apex of the vein was only about 10 ft. wide, as against the assertions of the St. Louis witnesses that its width was 55 ft.), and awarded the St. Louis Co. damages for the amount of ore extracted from the vein after it had departed from the compromise ground, aggregating 1,912 tons, valued at $237,470.40. The court had instructed the jury that if they found in favor of the plaintiff, they should include in their verdict interest at 8 per cent. per annum on the value of the ore extracted in 1893. As nearly 16 years had elapsed, the interest amounted to considerably more than the value of the ore. From the above amount was deducted the value of 218 tons of ore taken by the St. Louis Co. from beneath the compromise strip, amounting to $34,341.38, including interest—making the verdict $203,129.02. Upon a writ of error the judgment was reviewed by the Circuit Court of Appeals, where

it was affirmed (183 Fed. 51), and a petition for a writ of certiorari was denied by the Supreme Court of the United States on March 6, 1911. The Montana Co. decided to offer no further resistance, and in due course the property was sold by the sheriff to the plaintiff.

In the foregoing chronology of the litigation and analysis of court proceedings, Messrs. E. C. Day, C. F. Kelley, and L. O. Evans have kindly given the writer great assistance.

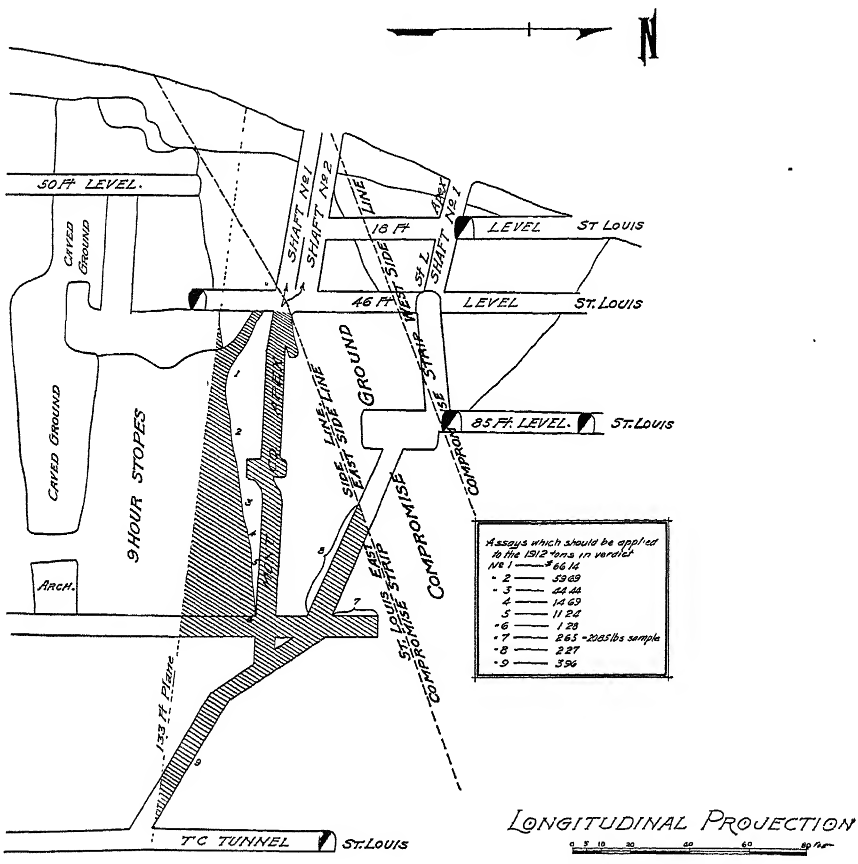

FIG. 4.—LONGITUDINAL PROJECTION OF 9-HOUR WORKINGS

Reviewing this history, we find that the litigation in its various phases required in the aggregate about five months in the four trials on questions of fact, and that it reached the State Supreme Court once, the Circuit Court of Appeals five times, and the Supreme Court of the United States four times. Furthermore, much time was occupied by the courts in many preliminary hearings.

The jury by their verdict showed that they did not accept the wide-vein theory of the plaintiff, for, if they had done so, they would have

awarded him damages for the proceeds of 31,592 tons of ore, instead of 1,912, which was about the amount admitted by the defendant as having been extracted by it under its own surface, but from that part of the vein having its apex partly within the St. Louis claim, west of the compromise strip. The award of $237,470.40 must have placed an original value of about $55 per ton on the ore. Fig. 4 shows the extent of the excavation made by the Montana Co. north of the 133-ft. plane and east of the compromise ground, and nearly all of this work was done in and beyond the extreme northern limits of the pay ore. Many samples were taken, before the trial, from the ore remaining in these workings, and the assays were submitted in court, giving what was thought to be ample proof that the material extracted did not return the company a profit of $15 per ton. Samples had also been taken as the work progressed; but the samplers and assayers of that time were either dead or out of reach, and the company could not prove its records by personal testimony. Furthermore, believing fully in the validity of its title to the compromise ground and to all the mineral therein contained, and that no adverse rights could be successfully claimed beyond this strip and within the 9-Hour location, as patented, the defendant had not taken the precaution to run the ore in question through the mills by itself, thereby placing on record its bullion yield. Moreover, there was a metallurgical advantage in working it with ore from other parts of the mine.

The advocates and defenders of our mining law insist that in no way, except by giving the discoverer of a vein the right to follow it on its dip under adjoining ground, can he realize the full benefits to which he is entitled. But in this case, the plaintiff was not suing for any rights directly pertaining to his discovery vein. His demands were based entirely upon an incidental vein, the existence of which was unknown to him when he made the St. Louis location; and this vein only skimmed along his side line. Yet the grantees of the actual discoverer of the lode in question finally lost the entire property as a result of these demands. With no development along the vein, the strike in the 9-Hour discovery led the locator to believe that in compromising with the St. Louis, he would have the apex of the lode within his claim from end to end; and, according to all considerations of equity and justice, the worst that should have happened in consequence of his lack of knowledge of the course of the vein, should have been the loss of the ore included within the vertical boundaries of the St. Louis claim, excluding the compromise ground. But what happened? By the application of the apex law, he was deprived of all ore in the vein he had discovered up to the 133-ft. plane, and was adjudged to be liable in damages to the St. Louis Co. for more than $200,000, covering 1,912 tons of ore which he had extracted from under his own surface. Furthermore, if the jury had accepted the wide-vein theory of the St. Louis witnesses, and had given it extra-lateral ownership to all

the ore up to the 268-ft. plane, the 9-Hour locator would have had *no rights in his discovery shaft*, and would have been a trespasser, and liable in damages, when he took a little sack of ore from there to the assayer, so that he could support the affidavit in his location notice, to the effect that he had made a valid discovery.

Can any one describe an instance where such injustice has resulted in the operation of the mining laws of other countries? With extra-lateral rights abolished, underground rights would be settled quickly on mathematical planes and years of litigation, with attending costs, would be avoided.

Discussion

Frederick T. Greene, Butte, Mont.—Mr. Goodale's very excellent history of the Drumlummon litigation educes certain reflections, which, while not obviously germane to his subject, are allied to the practical operation of mining lawsuits.

Most apex litigation necessitates many intricate problems involving the intersections of plane surfaces with one another. A very simple problem of this kind is indicated in Fig. 4. The vertical plane through the St. Louis side line cuts the vein and the line of intersection is represented by a bent line—bent, because there is a change in the dip of the vein producing a like change in the line of intersection. In consequence, a jury, probably composed of men who never even heard of descriptive geometry, is required to decide as to the cubical contents of this irregular polyhedron. In this particular instance the necessary knowledge is of the simplest, but there have been cases in which the question of damage involved some very intricate geometrical problems. In the solution of such problems it is essential that the ability to mentally depict the three dimensions of a body in their proper relations be invoked. In my own experience I find that many engineers who have had a course in descriptive geometry lack the power to correctly place the third dimension in its relation to the other two. Now, if *they* cannot comprehend a problem involving these points how much less capable must be the average juror. Nor is it at all probable that the average District Court Judge is much more successful in this than the juror, and the result of this failure, and of the fact that many other of the problems involved in "apex suits" are likewise incomprehensible to the judge or juror, is, that the attitude assumed by both judge and jury becomes that of a referee in a game; the victory goes to the side which "plays the game" according to the rule which appeals to that particular judge or set of jurors.

Senator Thomas J. Walsh, Helena, Mont.—I should point out the one apex proposition which was determined in this St. Louis-Nine Hour litigation.

There ran along in this litigation the question of what right would exist in the case of split apex—that is, where a portion of the apex was within one claim and a portion within another claim. That question was determined in another case.

In Fig. 3 of the paper you will see illustrated what is called the 108-ft. plane and the 135-ft. plane. The apex of the vein in question is quite wide. Going now to the upper left-hand corner, you will observe that coming from the left is the apex of the vein. It reaches the Nine-Hour or compromise ground, at what is indicated as the 108-ft. plane. At that point it begins to enter the comprromise gound, but t is not all within the compromise ground until the 135-ft. plane is reached.

Now, the question arose as to where the rights of the St. Louis Co. ceased—whether its rights ceased when the vein first began to enter the compromise ground at the 108-ft. plane, or at the plane at which it was all within the ground.

Judge Hiram Knowles, before whom it was tried, a judge profoundly familiar with the mining law, held that the rights of the St. Louis Co. ceased at the 108-ft. plane. That is, he held that as soon as any portion of the vein entered the compromise ground, the line parallel to the end line was there to be drawn defining the extent of the apex right. That view, however, was reversed by the Circuit Court of Appeals, which held that the 133-ft. plane bounded the extra-lateral rights (that, by the way, should be 133 in place of 135), and it determined the proposition that in case of a wide apex passing from one claim into another the owner of the apex could take all of the vein up to the plane which marked the most extreme point.

R. W. Raymond, New York, N. Y.—Having been personally engaged, as expert counsel and witness, in the first part of the litigation described by Mr. Goodale, and cognizant of its later stages, I desire to point out briefly some of its more important features.

1. This contest, from beginning to end, was waged by the St. Louis Co. against a company of British capitalists who had purchased the property, and invested their money for its development, in entire good faith, and who never undertook to do more than defend what they had bought and paid for, and honestly believed that they owned. That this company, after many years of litigation, was finally forced to submit to a practical confiscation of its supposed property, is chargeable, not to the action of its adversaries, who doubtless claimed only that to which they thought themselves legally entitled, but to the law which made such conflicts possible. The victims of the law in this case were those who had sedulously sought to obey it.

2. Mr. Goodale omits to mention in detail a number of interlocutory proceedings, which would swell the aggregate amount of the litigation involved.

3. This litigation involved several "leading cases," in which the U. S. Supreme Court settled important questions for the first time. But, before mentioning these, I would call attention to a point decided in the so-called "Triangle" case,[2] and not appealed, but subsequently decided in the opposite sense by the U. S. Supreme Court in another case.[3]

The latter decision set up a novel doctrine as to the nature of the title of a possessory owner of mineral land by location. The statute said that such locators should have "the exclusive right of possession and enjoyment of all the surface included within the lines of their locations;" and this was naturally construed by everybody to mean that this possessory title, so long as it was kept valid by compliance with legal requirements, was equivalent to ownership, so that no one could intrude upon the surface which it covered without committing a trespass; and that, consequently, no one could establish a location in the required rectangular form by putting his corner stakes on another man's ground, and then, in his application for patent, excepting the ground already owned by his neighbor, but claiming the rest as a valid location, whatever its shape. But the U. S. Supreme Court held, in the later Del Monte case cited above, that the locator was not an owner, and that "imaginary boundaries" might be drawn for a later location on the surface of his location, so as to secure extra-lateral rights, not impairing *his* rights.

The Montana statute, authorizing the inspection and survey of a mine, to ascertain whether a trespass had been committed, and the extent of damage thereby inflicted, *for the purpose of getting facts for the commencement of a suit*, was a decided novelty. According to the previous practice, a party might apply for such an inspection, after he had brought a bill in equity, just as the complainant in a civil suit may apply for permission to examine the defendant prior to trial; because the commencement of the suit puts the question or the property concerned within the jurisdiction of the court, and places the complainant under serious responsibilities and pecuniary liabilities. But it was a startling proposition that a party could go before a court and say, "My neighbor is mining much ore; and I would like to know where his bonanza lies, and whether some of it is not mine by extra-lateral right or otherwise. I will not take the responsibility of beginning a suit, because I do not really know that I have any ground for legal complaint, and I do not wish to frame a complaint, without first ascertaining just what to claim, and where, so as to secure the greatest advantage by victory—or else, discovering that I have no case, so as to avoid fighting altogether. I therefore ask the court to order a survey of my neighbor's mine workings for the purpose of giving me the information I desire"—and that the

[2] Montana Co. *vs.* Clark, 42 Fed., 626.

[3] Del Monte Mg. Co. *vs.* Last Chance Mg. Co., 171 U. S., 55.

court might make such a decree, without requiring, as a condition precedent, the commencement of a suit.

When I say this was new doctrine, I do not mean that similar statutes did not exist in other States. It is enough to say, that the question was carried to the U. S. Supreme Court in this case, on the proposition that the decree authorizing entry, survey, etc., upon private property in advance of any other proceeding, was not "due process of law," and therefore that the statute authorizing it contravened the Constitution of the United States. The U. S. Supreme Court (in 152 U. S., 160) upheld the constitutionality of the statute. I think this decision was correct, though it disappointed my clients, and established a possibly dangerous precedent.[4] For I hold it to be a sound principle of American equity practice that a court may order (under proper safeguard against injury, and bonds for possible damage, to property) the entry upon private property, for the purpose of ascertaining facts not otherwise to be known, and necessary to the just decision of a question before it. The Montana statute authorized a court to do this, when there was no question before it. But this extension of judicial authority was a necessary result of the apex law; and any evils which may flow from it are directly chargeable to that law, which conveys mining rights so vague, and so dependent upon geological phenomena, that nothing but an underground survey can determine them. In order to prove title, every stope in a mine must be traced to an apex; every branch of a vein must be connected with an apex right, etc.; and there is no doubt that, under this law, mining operations may be (and sometimes are) extended by crosscuts underground into veins not within the extra-lateral right of the operator. Congress having established the (undoubtedly constitutional) apex law, State statutes, necessary to its just administration, ought not to be lightly regarded as unconstitutional; and, while I am still inclined to think it would be wiser to require the commencement of a suit before the application for a survey, it seems to me that the Montana statute should not be condemned as omitting to provide a "due process of law."

The extent to which the apex law has thus required the enlargement of judicial power is amusingly illustrated by a mining case in British Columbia, of which I give an outline, omitting names, dates, and other details, as not necessary to my present purpose. British Columbia, at one time, adopted the apex law, and, after some years of experiment and amendment, abandoned it, returning to the system of "square locations" and vertical boundary planes. Long afterward, a controversy arose between two mines, involving the extra-lateral right acquired for one of them by its original location. The evidence showed that *A* had on the

[4] The danger is, perhaps, not great; for the applicant for such a survey, "fishing for evidence in advance," can get it only in the discretion of the court, and would doubtless have to show reasonable cause.

surface of his location the plain apex of a vein, which he had followed with an incline down to a point where it reached the vertical plane through his side line. Here A was stopped by an injunction, forbidding him to trespass upon the ground covered by the location of B. Meanwhile, B, in working his mine, had followed upward a precisely similar vein, until he reached a point 12 ft. (if I remember correctly) on the dip, from the said boundary. It was this vein that A claimed, under his apex right. But the continuity and identity could not be proved beyond possible doubt, except by driving, on B's ground, from the bottom of an excavation of A, an incline to reach the top of B's excavation; and A's application to have this connection made under the direction of the court was refused. In vain were the opinions and decisions of American courts, interpreting the apex law, produced in argument. They were received with complimentary comments as worthy of consideration, but not authoritative in a Crown Province, taking its precedents from the British Chancellor or the House of Lords. It was very difficult to find such precedents; for the British decisions had never dealt with the apex law; but finally (to skip all intermediate steps) an equity decision was discovered, which proved to cover the point. It was in a dispute, involving the responsibility for an evil odor, proceeding from a system of drains; and since the actual source of the evil odor could not be ascertained without investigating the connections of the drains under an adjacent public highway, the court ordered the digging-up of that highway, in order to obtain the information necessary to a just decision. But the highway belonged to the King, and if the King's property rights could be violated for such a reason, how much more those of a private subject! It was this fragrant precedent that ultimately secured for A an order of court, authorizing the excavation which established his extra-lateral right.

Many other points in Mr. Goodale's paper might be made the subjects of extended comment. But I will mention only one. The complicated litigation over the "compromise ground," which ultimately ruined the Montana Co., was due to the form of the agreement (and the subsequent deed, conforming thereto) which conveyed only a given area, "with the mineral therein contained," and did not name the extra-lateral right. If the "compromise ground" had been conveyed without any such specific qualification, the conveyance might easily have been construed, under the principle laid down in the old Eureka case, according to the custom of miners, as conveying all the rights appertaining to the ownership of the ground as part of the senior Nine Hour location. That was undoubtedly the original intention of the parties. But the specification in a deed of what is actually conveyed, may exclude the consideration of other things orally promised or mentally intended. It may fairly be said, therefore, that the hardship and injustice suffered by the Montana Co. in connection with its "compromise ground," were due to the error

of its original grantor. Nevertheless, it still remains a pertinent objection to the apex law that such punishments of innocent error and such hardships to *bona fide* investors can take place under its honest administration.

M. K. RODGERS, Santa Monica, Cal.—My early work was in Butte, and I remember one of the first things I noticed there on the apex law was a fraction owned by a gentleman in Butte. Considerable ore was being taken out. The Anaconda Co. was interested in the ore taken out, and found that there was a small vein on the side of the mountain. We got into litigation and we found that both were taking out ore which did not belong to either, but which belonged to the Anaconda Co.

My experience in British Columbia and in this country led me to this: I eliminated the apex law from all concerns or properties, and we would not have anything to do with a mining company that based its title on the apex law, and a bunch of lawyers and a bunch of innocent Western jurors to give you justice.

The expert's work is only good until further development works changes; change conditions, and he will then change his opinion. I found it worked well to eliminate the apex law from my work entirely. The indefiniteness of the apex conditions is such that no apex law will cover it. It is much easier to do mining business in Canada, for the reason that their laws are definite, and ours are not.

If you own a claim at the head of the Copper river to-day, and another on the British side of the line, it will cost the American anywhere from $1,000 up to do $100 worth of work; while on the other side you can remit your check and do the work.

In British Columbia you have something in the way of an abstracted title. As soon as you do your assessment work you must describe what you do. At the end of five years, you have something. On the Alaska side you do not even have a record of the work of two years ago, and at the end of five years your title depends upon whether there are more people there to swear you did your work or more people who will swear you did not do the work. A wise Swede out there had a claim, during the days when everything was jumped. He had seven or eight corners at his corner post. Some one noticed it and said, "Somebody has been jumping you too, have they?" He said, "No, I jump myself every six weeks."

CHARLES H. SHAMEL, Springfield, Ill. (communication to the Secretary*).—Mr. Goodale's history of the litigation involving the Drummummon lode is a clear and interesting account of a celebrated controversy involving the apex law. It is written at this time for its bearing on the proposed repeal of the apex law; and its intended moral is

* Received Feb. 3, 1914.

that the apex law is "immeasureably bad." He asks: "Can any one describe an instance where such injustice has resulted in the operation of the mining laws of other countries?" Unfortunately, I am not familiar with the history of mining litigation elsewhere than in the United States and so cannot answer the question exactly as proposed. There are, however, only two practical alternatives for a law governing underground rights anywhere in the world: allowing the vein to be followed wheresoever it may lead (the principle of the apex law); and limitation by vertical planes through boundaries. The latter alternative rules in the greater part of the United States (a fact which appears to be overlooked by many writers) and, without going from home, the examples the gentleman asks for can be readily furnished and these entirely demolish any argument against the apex law founded on the Drumlummon case. A striking example is the bitter litigation about the zinc deposits at Franklin Furnace, N. J., lasting in various forms nearly half a century. I have outlined this remarkable litigation elsewhere and it would be impossible to do so here within allowable space.[5]

Another recent example is the enormously protracted (about 3 months for one trial) and expensive (about $60,000 for court costs alone) trial in the U. S. district court in New York City, which resulted in the conviction and sentence to the penitentiary for fraud by a mining company of Julian Hawthorne, and a doctor and an Austrian whose names just now escape me. There are very numerous examples of this kind equal to the Drumlummon litigation. I happen to know personally of a litigation arising in a rural county in Illinois about the corporate affairs of an Arizona mining company which lasted 13 years, and resulted in the wrecking of the company, which previously stood in the not overcrowded rank of dividend payers.

A search would doubtless disclose in the legal history of the United States many other equally important mining litigations also not involving the apex law at all; so that it is utterly fallacious to argue that the Drumlummon case justifies the repeal of that law. From scattered hints in reading, I believe that other mining countries would furnish also many examples of just as important litigations. I have conclusively shown in my main contribution to this discussion, by an actual count of the mining cases, that the apex law causes much less than its proportionate share of mining litigation, instead of nearly all of it, as most non-legal writers seem to assume. The instances I give above prove that its lawsuits are not more protracted or expensive than other mining litigation.

If injustice resulted from the final decision in the Drumlummon

[5] See Shamel's *Mining, Mineral and Geological Law*, p. 43 *et seq.*, where the citations to the original reports of the case are given.

case, as Mr. Goodale seems to believe, the fault lies not with the apex law, but with the existing instruments and methods of legal procedure. I am as strongly in favor as any one can possibly be of a thorough-going reformation of our entire legal system. It is foolish to try this kind of a case or, in truth, any kind of a case before a jury, if an honest and impartial judge can be found to try it; and, under a proper legal system, this could be done without fail. Our Anglo-American jury system is an archaic survival of an entirely different state of society and stage of civilization and is as crude and inefficient as the solid-wheeled carts of Mexico compared to a railway train.

True it is, as Fred T. Greene observes in discussing Mr. Goodale's paper, that if the dip of the vein changes, or, to state it more accurately, if the boundary of the ore body is a warped surface, its intersection with St. Louis's side line will be a bent line, but this is not any argument whatever against the apex law. If it has any bearing at all it is just the contrary; for it is one of the problems which will arise oftenest under the opposite legal principle because liable to occur whenever the vein passes under *any* boundary, whereas under the apex law it cannot occur more than one-half as often; that is, only when the vein passes out beneath an *end* line. If it passes out beneath a side line no jury or judge will have to worry about an irregular polyhedron, for the very simple reason that the miner can legally excavate as far as he sees fit without liability to anybody.

In reality, the situation instanced has absolutely no application in the apex controversy; and its attempted use is a striking example of the confusion of thought or desperate dearth of sound argument suffered by the opponents of the apex law. So far as the difficulty Mr. Greene mentions is an argument for anything, it is, like Mr. Goodale's, an argument for a radical reform of our entire legal system, or, perhaps, even for the abolition of courts altogether, allowing mining disputes to be adjusted by the primitive combat method. I would further observe, however, that so far as my experience goes I never saw either a judge or jury obliged to struggle with such a problem as calculating the cubical contents of an irregular polyhedron. The universal practice is, when such questions arise, that one or more competent engineers or other experts are placed on the witness stand and asked the question as to the contents of the irregular polyhedron of given dimensions. If he or they are competent, it is impossible that there would be any doubt about the testimony; and it would certainly be adopted by the judge and jury in arriving at a verdict. Consequently, such problems, even under our present legal system, would be decided according to the best knowledge of engineers or other experts; and the ignorance of judge and jury about descriptive geometry does not matter. In fact, justice can be more nearly attained, and I would rather try a technical or scientific case before a judge and

jury entirely without knowledge of the technical or scientific principles involved, because if the expert who testifies and furnishes the technical information is mistaken or false it can be exposed and thrown out, but it is impossible to know and correct technical mistakes which may lurk in the minds of judge or jury supposed to be familiar with them. In my judgment, neither Mr. Goodale nor Mr. Greene advances any arguments justifying even remotely the proposal to repeal the apex law.

The Initiation of Title to Mineral Lands

BY ALBERT BURCH, SAN FRANCISCO, CAL.

(New York Meeting, February, 1914)

AN analysis of this subject demands a study of the theory and practice of the present system, conclusions as to its merits, and recommendations for remedying its defects if any be found.

Theory of the Present Law

The theory of the present law with reference to lode locations contemplates the existence upon the surface of mineral-bearing veins which have clearly marked boundaries, and which can be so readily traced that a locator may immediately mark the boundaries of his 600 by 1,500 ft. claim in such a way that the vein will pass through both of its end-lines. It also supposes that, having discovered such a mineral-bearing vein, the locator will at once post a notice upon such discovery, mark the boundaries of his location in such a manner that they can be readily traced, and from that time forward have absolute title to the ground embraced within such boundaries, as against every person except the United States.

For initiating title to placer ground, the law presupposes the discovery of a valuable mineral deposit; but not necessarily in place, as in the case of lode claims; and the location must be made to conform "as nearly as may be" to the legal subdivisions of the United States public land survey. When the placer law was extended to include the acquisition of title to oil lands, no exception was made as to the necessity for the discovery of valuable mineral in advance of location!

Practice under the Present Law

Nature did not make all veins clearly defined and readily traceable upon the surface; nor did she, in all cases, leave upon the surface which overlies important ore bodies such outcrops as would in themselves be considered valuable; and the citizen of the United States has in the past endeavored to steer his course between the mandates of the law and the limitations of nature.

Until quite recently, it has been possible to obtain a patent for any-

thing called a mining claim, regardless of the character of its discovery. The Department of the Interior is now insisting, however, upon a more strict compliance with the letter of the law; and it has become almost, if not quite, necessary to demonstrate the existence of payable ore within the limits of a mining claim in order to obtain a United States patent therefor (but not, of course, in order to make a location giving the locator a possessory title against all except the United States).

Whether this change of policy on the part of the Department of the Interior has resulted in a general attempt on the part of locators to adhere more closely to the letter of the law relating to discovery, the writer is unable to say. But, in the past, thousands of lode claims have been located, upon which there were not only no outcrops of commercially valuable ore bodies, but no outcrops of any nature whatsoever. The boundaries of claims have not been so placed that the veins found within them cross their end lines at the surface, nor have their boundaries been so marked upon the surface as to be readily traceable. The result of this laxity, in conjunction with the extra-lateral right granted by the law, has been costly litigation, which has made the American mining law a by-word among mining investors, and has, in many cases, actually prevented the investment of both domestic and foreign capital in American mines.

Placer claims, except for acquiring title to oil lands, have ceased to be very important in the United States; and, even in the past, comparatively few have been located without some semblance of discovery.

Faults of the Present System

The chief faults of the present system, as viewed by the writer, are but two in number:

1. If the law be not strictly complied with, the result is expensive litigation and uncertain titles.

2. If the law be strictly enforced, then it is not possible to obtain satisfactory title to such areas of mining ground as are necessary for economical operation by present-day methods.

Remedies Recommended

1. The writer suggests that "discovery" as a prerequisite to the location of all classes of mining claims be abolished in law, as it has been, for many years past, in practice.

2. That in order to avoid surface conflicts, a claimant be required to have his claim surveyed immediately after location by a salaried surveyor in the employ of the government, and that the government charge such fees for this service as are estimated to be necessary to cover the salaries and office expenses of the surveyors.

3. That the number of lode claims which an individual, corporation, or association may locate or acquire in any given mining district be limited in such a manner as to prevent monopoly on the one hand and yet admit of the economical operation on a large scale which mining methods of the present day demand.

4. The writer is not sufficiently familiar with conditions governing the development of oil lands to enable him to make any recommendations regarding the initiation of title to oil-land claims, other than to say that "discovery" as a prerequisite is manifestly improper.

5. With reference to placer locations other than of oil lands, the placer law should be made applicable only to those deposits of valuable mineral which lie above the surface of bedrock, and other provisions should be made for the initiation of title to bodies of iron ore and such stratified deposits as phosphate rock, gypsum, etc., the location of which has heretofore been considered as possibly included within the provisions of the present law governing the location of placer mining claims.

6. Buried river channels of gold-bearing gravel, which are found in California, and, to a limited extent, in other States, might be located under the law governing the location of lode mining claims, instead of that relating to placers, as at present.

Naturally, such changes as are suggested above would involve some change in the laws governing the maintenance of title to mining claims, but the discussion of that subject does not come within the province of this paper.

Discussion

M. K. Rodgers, Santa Monica, Cal.—I would like to call attention to a very important thing in this paper, and that is the survey of the claim being made immediately after location, or as soon as the prospector cares to do it. In British Columbia that is permissible, and it is allowed as one year's assessment work.

George A. Packard, Boston, Mass.—Speaking of a survey, I want to refer to the change in the manner in which prospectors and locators are doing work on their claims. Two months ago I went to Montana to look over claims for which patent was asked two years ago; and there were two discovery holes, about 50 ft. apart. One of those claims had been passed for patent by the Interior Department, and the other had not.

I will admit that in one claim there was good quartz-bearing ore, and in the other only some stringers; but at the same time there was a mining claim within 2 miles which had produced $20,000,000 according to a record I had seen. One of these claims had been turned down for patenting as "non-mineral land." It had been relocated and the owner was driving a useless cross-cut tunnel in an endeavor to find some quartz or

copper to satisfy persons sent out by the Department to make the examination.

There were some eight claims, so located that a tunnel on one of the veins, with cross-cuts, would have developed all very advantageously. But the owner had been obliged to spend $500 on each individual claim, and to throw it away, as he had been told by the engineers who made the survey for the patent that if he made an expenditure of $4,000 all in one place, which would be greatly to his advantage in developing the property, undoubtedly the claims would not be passed for patent. That is one thing which has arisen as a result of change of policy in the Department.

Now, taking up the matter of survey of the claim: I agree with the gentleman who has just spoken, that that is an extremely desirable thing, and it should be permissible that the claim should be surveyed and the cost of survey be applied as a portion of the assessment work, of the $100 worth of work, if we are to have such a feature in our law. But I do not think survey of the claim should be made obligatory. There are many prospectors who have not the money to pay for a survey of the claim, but they can go out and do $100 worth of work on the property; and that is of some value in making the property salable, while the survey is not as valuable.

We have not enough prospectors in the West to find as many mines as the mining investors of the East would like to buy if they could see something worth buying; and I think it would be a great mistake to put into the law any requirement which would make it more difficult for the prospector to go out and establish title to his claim. I think the law should be such that the *initiation of the possessory right should be as simple and inexpensive as it possibly can be, and yet at the same time give us a record, and a title, which would be unquestionable.*

Horace V. Winchell, Minneapolis, Minn.—I am reminded that there are surveys and surveys. Last summer I visited Patagonia. I had a map furnished by the Argentine government in Buenos Aires. I traveled 3,000 miles, and each applicant for an oil concession had to advance 1,500 or 2,000 pesos for surveys. They did so. I organized an expedition and went out, and as I approached I saw white stakes, but there was not a single mark on a single stake to show what had been surveyed.

Good Ideas in the Mining Laws of British Columbia and Mexico

BY F. L. SIZER, SAN FRANCISCO, CAL.

(New York Meeting, February, 1914)

THE mining regulations of British Columbia and Mexico present some features which might well be copied in the United States, if we are to have a complete revision of the laws governing mining titles.

1. First and foremost is the "square" location, which would mean the abolition of extralateral rights. This is a condition in both of the countries above named which has seemed to work no hardship upon any one, and certainly the limitation of underground rights by vertical planes through all lines makes a locator's rights clear. In view of the long and costly litigation which has involved so seriously many of our most important mining districts, it would seem to be the part of wisdom to avoid a repetition of similar trouble on titles of lode mining claims, by the enactment of a law similar to that in force in British Columbia.

Objections have been raised by representatives of English companies to the investment of large amounts of money in mining operations in the United States, because of the insecurity of title under the present apex law; and the statement has been made to me personally by one of the largest English operators, that he would never again consent to the purchase of mines in the United States, preferring Mexico with all its revolutionary troubles to the danger of encroachment upon his underground rights by an unscrupulous neighbor.

Without going into further argument as to the desirability of the "square location," it should be sufficient to say to those who are inclined to "let well enough alone" and still stick to the "law of the apex" that there have never been any serious objections raised to this feature of the square location in either British Columbia or Mexico. There are well founded and logical reasons for abandoning the doctrine of extra-lateral rights since it is so difficult of interpretation; the most natural substitute being a law similar to that of British Columbia, giving to each locator an area 1,500 ft. square.

I would advocate the right to locate adjoining claims of equal extent on either side of the *discovery* claim, on the *strike* of the lode, subject to a reasonable requirement in the matter of work upon them; and in the case of a vein dipping flatter than 45° from the horizon, or in case of a

"deposit," I would also favor the right to locate one additional claim (without actual discovery upon it) on the side toward which the lode or deposit dips.

2. For the official known as Gold Commissioner, in British Columbia, there can probably be substituted a county official or, perhaps, the State Mine Inspector, whose business it shall be to inspect the yearly work done upon all claims held by possessory right. He could pass upon the sufficiency of the work and make suitable record of the same in the county recorder's office. This mode of notification to the public would insure honest work of the full value of $100 per claim each year, up to the time patent is secured; and some method, copying, in part, the British Columbia law, will probably be desirable.

3. The suggestion contained in the foregoing paragraph presupposes the desirability of "annual work" upon mining claims rather than the payment of a government tax, as is the law in Mexico. This is a point which is worth careful consideration, *before the enactment of any law.* The present disturbed condition of affairs in Mexico is an argument against perpetuating possessory title by means of annual tax paid to the government, though it may be justly said that conditions similar to those in Mexico can hardly arise in the United States.

4. It certainly does not seem wise to adopt what has been done in many of the English colonies: namely, retention of jurisdiction by the government over all mineral lands, as that would amount to a leasing system, and there is a preponderance of opinion adverse to this method among active mining men all over the United States.

In conclusion, I have attempted to discuss only those features of the laws of British Columbia and Mexico which I think would be applicable in the United States, leaving to others who are more familiar with the mining statutes of other countries the presentation of their views.

Discussion

Sidney J. Jennings, New York, N. Y.—This paper seems to open up what is desirable in the new law of the United States. I think that is a point on which the Institute would like to be heard when new laws are actually proposed by the government in the shape of bills before Congress. And it would be wise before any new legislation is passed to have a Commission gather the views and opinions concerning the desirable features of mining laws of other countries, and those which appeal most strongly to the operating engineers in the United States.

W. L. Cumings, Bethlehem, Pa.—Mr. Sizer's paper suggests something which I have not noticed in many of the papers on this subject, and that is, more comparisons drawn between the mining laws of the United States, and those of other countries, showing the good and bad

features of each. We all know that there are serious objections to some features of the mining laws of the Spanish-American countries, such as, for instance, confusion arising from the classification of mineral deposits. This has given rise in Cuba to a lawsuit which compares in magnitude with many of the famous apex-law cases.

In this connection it would seem that descriptions of some of the complicated ore deposits of other countries could be used as examples showing the litigation that would undoubtedly have followed had the same been located in the United States.

WILLIAM B. MCKINLAY, New York, N. Y. (communication to the Secretary*).—1. The "square location." On account of the extremely irregular nature of some ore deposits, it would perhaps be restrictive to the point of injustice were a miner compelled to locate his ground in the form of one large square. In the various contributions which I have had the privilege to intrude in the extra-lateral wrangle, I have consistently urged that locations should be made in a form resembling the Mexican "pertenencia" system; *i.e.*, blocks of ground bounded on the surface by true squares of moderate size (or rather by the lines of vertical projection of a true square upon the surface of the ground) and bounded laterally by vertical planes passing through the suface lines.

About 10 years ago there was introduced in the House of Representatives a bill prepared by me and containing some of the "innovations" which I advocated. The same bill, with a slight change, is at present being considered for introduction in the U. S. Senate, though at present overshadowed by matters of more urgent importance, such as the Mexican policy and the Canal tolls question. The present text of this tentative bill is as follows:

A BILL to amend sections twenty-three hundred and twenty, twenty-three hundred and twenty-two, twenty-three hundred and twenty-three, and twenty-three hundred and twenty-four of the Revised Statutes of the United States, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

That sections twenty-three hundred and twenty, twenty-three hundred and twenty-two, twenty-three hundred and twenty-three, and twenty-three hundred and twenty-four of the Revised Statutes are hereby amended so as to read as follows:

SEC. 2320. Mining-claims upon veins or lodes of quartz or other rock in place bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits, heretofore located, shall be governed as to length along the vein or lode by the customs, regulations, and laws in force at the date of their location. A mining-claim located after the passage of this act, whether located by one or more persons, shall be rectangular in form and may equal, but shall not exceed, four contiguous mining-blocks, each of which shall be a square with sides measuring, as near as may be, six hundred and sixty feet. Provided, however, if it be impracticable to procure blocks of true squares because of a previous valid location the new location shall be bounded on all sides by

* Received Mar. 20, 1914.

straight lines at right angles, except along the boundary of such location or locations. No claim shall be granted for an area less than that of a mining-block, except when, from any cause, a grant of that quantity cannot be made. No claim may be located until the discovery of a vein, lode, ledge, or deposit within the limits of one of the mining-blocks; though a single block may be provisionally claimed as a prospecting claim, in the manner described in Section 2323.

Sec. 2322. The locators of all mining-claims heretofore located or which shall hereafter be located, on any mineral vein, lode, ledge, or deposit, situated on the public domain, their heirs and assigns, where no adverse claim exists at the passage of this act, so long as they comply with the laws of the United States, and with State, territorial, and local regulations not in conflict with the laws of the United States governing their possessory title, shall have the exclusive right of possession and enjoyment of all the surface included within the lines of their locations, and of all veins, lodes, ledges, and deposits included within the territory bounded by vertical planes passing through the lines of their locations.

Provided, however, that the locators of mining-claims located prior to the passage of this act, their heirs and assigns, shall have the right to exploit or mine all veins, lodes, and ledges throughout their entire depth, which shall have been discovered by the said locators or their heirs and assigns and actually exploited or mined prior to the passage of this act, although such veins, lodes, or ledges may so far depart from a perpendicular in their course downward as to extend outside the territory bounded by vertical planes through the side-lines of the surface locations.

But their right ot possession to such outside parts of such veins, lodes, or ledges shall be confined to such portions thereof as lie between the vertical planes passing through the end-lines of their locations. And nothing in this section shall authorize the locator or possessor of a vein, lode, or ledge which extends in its downward course beyond the vertical planes through the side-lines of his claim to enter upon the surface of a claim owned or possessed by another. Nor shall anything in this section be so construed as to authorize any locator or possessor of a mining-claim to exploit or mine, outside of the limits of the territory bounded by vertical planes passing through the lines of their location, any vein, lode, or ledge not discovered, exploited, or mined prior to the passage of this Act, even though the top or apex of the vein, lode, or ledge may be considered to lie within the limits of the above-described territory. And the failure to exercise the right to exploit or mine beyond the side-lines of a claim during a period of twelve months at any time subsequent to the passage of this Act shall be considered as an abandonment of such rights.

Sec. 2323. A single mining-block may be provisionally located as a prospecting block or prospecting claim, before the actual discovery of a vein, lode, ledge, or deposit; and the locator of a prospecting claim shall have the right to sink shafts, run tunnels, and carry on other exploratory work for the discovery of mineral, within the limits of the block located. Locations of prospecting claims, conflicting with prior locations on which work is being prosecuted with reasonable diligence, shall be invalid. And failure to prosecute the work on a prospecting claim for six months shall be considered as an abandonment of the right to all undiscovered veins, lodes, ledges or deposits within the limits of the prospecting block. But the rights of the locator of a prospecting claim, as long as it is merely a prospecting claim, shall not interfere with the rights of the locator of a mining-claim to choose such location as he desires for the additional mining-blocks adjacent to the mining-block in which he has actually discovered a vein, lode, ledge, or deposit of mineral.

Sec. 2324. The miners of each mining district may make regulations not in conflict with the laws of the United States, or with the laws of the State or Territory in which the district is situated, governing the location, manner of recording, amount

of work necessary to hold possession of a mining-claim or a prospecting claim, subject to the following requirements:

The location must be distinctly marked upon the ground so that its boundaries can be readily traced. All records of mining-claims hereafter made shall contain the name or names of the locators, the date of the location, and such a description of the claim or claims located by reference to some natural object or permanent monument as will identify the claim. On each mining-claim located after the passage of this Act, and until a patent has been issued therefor, labor shall be performed or improvements made during each year, to the value of not less than twenty-five dollars for each mining-block or fraction thereof. On all claims located prior to the passage of this Act, not less than one hundred dollars worth of labor shall be performed or improvements made within eighteen months from the passage of this Act, and each year thereafter until a patent has been issued therefor; but where contiguous claims are held in common, such expenditure may be made upon any one claim. And upon a failure to comply with these conditions, the claim or mine upon which such failure occurred shall be open to re-location in the same manner as if no location of the same had ever been made, provided that the original locators, their heirs, assigns, or legal representatives, have not resumed work upon the claim after failure and before such re-location. Upon the failure of any one of several co-owners to contribute his proportion of the expenditures required hereby, the co-owners who have performed the labor or made the improvements may, at the expiration of the year, give such delinquent co-owner personal notice in writing or notice by publication in the newspaper published nearest the claim, for at least once a week for ninety days, and if at the expiration of ninety days after such notice in writing or by publication such delinquent should fail or refuse to contribute his proportion of the expenditure required by this section, his interest in the claim shall become the property of his co-owners who have made the required expenditures.

It is not expected, nor is it entirely desirable, that the bill in its present form should be finally enacted as a law. Certain details have been incorporated in it simply for the purpose of exciting discussion, so that when the final draft shall have been prepared it will contain the features which promise to afford the healthy stimulation which the mining industry needs.

The present laws establishing the method of location of mineral lands situated in what are known as the public lands of the United States of America were based upon mistaken ideas as to the nature of mineral veins and deposits. It was apparently assumed that all deposits existed in true fissure veins extending downward into the earth for an indefinite distance and rarely departing any great distance from the perpendicular.

It was deemed just, by the makers of the laws, that a miner should be entitled to mine throughout its depth any deposit whose apex or highest point he might discover in the course of working within the limits of his own claim; even though the deposit might extend beyond the bounds of perpendicular planes passing through the side lines of his own claim.

In the course of many years of mining work carried on since the enactment of the present laws, it has been learned that many mineral deposits have a character totally unlike that presumed in the original

premises. As a consequence, many long and bitter fights have been carried on in the courts (and out of court), involving claims to ore deposits mined and unmined. The trend of the deposits, often difficult to determine even under peaceful conditions of working, has in some instances been greatly obscured by the dynamiting of worked-out stopes by miners who desired to give themselves the benefit of the doubt.

Were the limits set by the definite bounds of vertical planes through lines of surface ownership, any disputes as to the ownership of ore could be resolved by simple surveying.

In the States where there is no Federal public land the Federal mining laws do not apply. Thus, for example, in the State of Michigan, in Houghton county, it was possible for the Tamarack Mining Co. to sink a shaft through several thousand feet of barren rock in order to tap the celebrated conglomerate copper deposit worked from the surface by the Calumet & Hecla Co. Had the Federal mining laws applied in that district, the Calumet & Hecla would have enjoyed a monopoly and have left as future ore reserves the deposit worked by the Tamarack Co. But, since rational laws governed the title to the said deposit, employment was given to many thousands of men and the sinking of the deepest mine shaft in the world was later justified by the results obtained by the Tamarack Co. Also, the sinking of the great Whiting shaft was undertaken by the Calumet & Hecla Co., partly due to the encouragement induced by its neighbor's success.

While it is desirable to limit the rights of possession of ore deposits by providing that all future locations shall give definite possession within the definite bounds of vertical planes, it is desirable that vested rights (previously granted by laws which, however irrational they may have been, nevertheless were the laws of the land) should not be taken away during the enjoyment of said rights. But it is not compatible with the principles of our government to continue to sustain monopolistic privileges of an indefinite character for the benefit of those individuals or corporations who neglect or refuse to exercise the indefinite privileges either for their own benefit or for the benefit of the community in general.

In my opinion it would not be correct to assume that the annulling of an unexercised indefinite privilege would constitute *ex-post-facto* legislation, because from the very nature of the extra-lateral right privilege the fact of the existence of ore beyond the side lines of a claim is not demonstrated to be a fact until the ore itself is uncovered and mined.

It is not claimed that the amendment of the mining laws will prove a universal panacea for all the ills which at present afflict the mining industry. But amendment along the general lines as suggested by the draft which I have submitted would certainly tend to stimulate prospecting activity and would force the owners of idle mines to either work their own mines or give some one else the right to search for mineral, with

reasonable protection covering the enjoyment of such deposits as they may find. It is extremely disconcerting to spend money in the development of a property and ultimately discover that the vein has its highest point under the surface of another, with the result that the apex owner seizes all.

In any event, legislation should not be undertaken too hastily. Men cannot be made honest by legislation. Nor should legislators assume that all men are dishonest by inclination. In cases where this latter assumption is made, the new freedom will tend to resemble a modified application of the British criminal system of ticket of leave.

2. The suggestion of the appointment of official inspectors or Commissioners is an excellent one. Where Federal lands are to be inspected, it is rational that the inspectors should be Federal officers rather than county or State officers. The enlargement of the Bureau of Mines, with a possible elevation to the status of a Department of Mines, seems to me to be the best solution.

I know of no person better fitted to plan the adaptation of the Bureau of Mines to this class of service than the present Director of that Bureau.

When the Congress shall have solved all the urgent matters of trust regulation, inter-oceanic transportation tolls rates, foreign relations, etc., perhaps they who dominate that joint legislative body will see the wisdom of authorizing the Director of the Bureau of Mines to select a Commission of practical miners and mining engineers to assist him in drafting the ideal bill.

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Why the Mining Laws Should be Revised

BY HORACE V. WINCHELL, MINNEAPOLIS, MINN.

(New York Meeting, February, 1914)

Scope of Discussion

THE laws here referred to are those which define the status of the prospector for mineral deposits in the soil or beneath it, establish his methods of procedure, protect him in his possession while searching for the subterranean treasures, and give him assurance of title when all required conditions have been fulfilled and valuable minerals discovered.

Regulations for the operation of mines and the safety and health of mine employees are likewise subjects of Federal and State legislation, but are not within the scope of the present program. Various features of our present laws will be discussed in detail by able students of the subject, and specific remedies will be proposed for the most glaring defects. It is my purpose to present in this paper a summary review of the reasons why revision is needed and demanded by the great majority of those in daily contact with the industry.

Reason Number One

The first objection to the continuance of the present law is that it was not planned by its framers and the Congress which passed it to apply to many of the kinds of mineral deposits, nor to the mining conditions, which are controlled by it to-day. In 1866, under the title, "An Act granting the right of way to ditch and canal owners over the public lands, and for other purposes," was surreptitiously smuggled into existence our first mining law (14 Stats. at Large, Chap. 262, p. 251). This law provided that "whenever any person or association of persons claim a vein or lode of quartz or other rock in place, bearing gold, silver, cinnabar or copper, having previously occupied and improved the same according to the local customs or rules of miners in the district where the same is situated," etc., a patent might be granted on certain conditions.

This was evidently an Act intended to validate claims already initiated, and to accord Federal recognition to mining locations made in

accordance with the customs and rules of the miners. And the only metals thus provided for were gold, silver, cinnabar, and copper.

In 1872 the substance of our present law was adopted, in an Act amending the Act of 1866, which was enlarged in scope to include all valuable deposits in lands belonging to the United States; although the limitations of the mining industry at that time and the idea in the mind of Congress are clearly shown by the more explicit wording of the Act (now Section 2320 of the Revised Statutes), which specifies "mining claims upon veins or lodes of quartz or other rock in place, bearing gold, silver, cinnabar, lead, tin, copper or other valuable deposits."

Placers had been made in 1870 subject to entry in the same way as lodes, and by various Acts Michigan, Wisconsin, Minnesota, Alabama, Missouri, and Kansas were fortunately excepted from the operation of the mining law, although just why they were so favored remains an interesting question for the student of history.

In 1892 Congress placed deposits of building stone under the placer Act (27 Stats. at Large, p. 348); and in 1897 the same action was taken with reference to petroleum (29 Stats. at Large, p. 526); and still later in 1901 the placer Act was extended to saline lands (31 Stats. at Large, p. 145).

By these various amendments Congress acknowledged that the language of the Act of 1872 in reference to "all valuable mineral deposits" is not to be literally construed; and by passing other special Acts for coal lands has again indicated the incompleteness and insufficiency of the mining Act of 1872. If we now mention the fact that rare earths, phosphates, potash deposits, natural gas, and sulphur are still unprovided for, or locatable under the same conditions as gold and silver lodes or placers, it will be at once apparent either that the law is stretched to-day to cover much for which it was not intended, or that it is in these respects entirely deficient.

Upon closer analysis its inadequacy and unwarranted extension become still more plainly apparent. The Act speaks of "veins or lodes of quartz or other rock, bearing gold, silver," etc., and there is no doubt that only such deposits were in the minds of its framers. The only mines of gold, silver, cinnabar, lead, tin, and copper in operation at that time in those portions of the country to which the law was made applicable were, or were supposed to be, on true veins or lodes; and these lodes had been discovered outcropping above, or lying immediately beneath, the loose surface materials. Only the richer ores were commercially valuable in those days of few railroads and fewer smelters, of primitive metallurgical knowledge and scarcity of technical graduates; and rich ores are the peculiar property of those veins and lodes which most nearly approach the old text-book ideal. Hence the law was naturally drawn to fit such deposits. On this point an eminent authority remarks:

"The author of the mining law had in mind the idea (seldom realized) that mineral veins were always fissures nearly vertical. The force of that observation is of peculiar significance here. From the entire law the conclusion is irresistible that Congress had in mind single distinct fissures, standing almost vertical, and generally thought to be distinct and separate from all neighboring veins, that is, independent of any theory or notion of zones, lodes or broad veins. Moreover, these veins were susceptible of being easily traced upon the surface . . . . . If the author of the law had been fully informed as to the facts of vein formation as now understood, it is very doubtful whether the law would have been enacted in its present form, and more probable that vertical bounding planes would have been the requirement."[1]

Those familiar with mining developments in the West during the past 20 years can instantly appreciate the force of this argument; but since these pages are prepared for many who have not this knowledge, it seems proper to go into greater detail.

Gold and silver ores are still looked upon as typically found in "veins or lodes of quartz." But the most important gold-mining developments at the present moment are in low-grade disseminations through schists and eruptive rocks, such as were never dreamed of by those who framed the law of 1872. Indeed, the Homestake, the Alaska Treadwell, and neighboring properties in Alaska, the majority of the mines at Leadville, the mines of the Kendall district, Montana, and of many other gold and silver districts in the United States, to say nothing of those in other countries, are so different from the deposits for which the law was created that only by a wide stretch of both the law and the imagination have they been brought within its provisions. It is noteworthy, too, in connection with the apex rights which the law purported to grant and which the miners were supposed to favor, that the statutes were not only ignored by miners in the flat veins at Leadville, but so persistently and successfully rejected by all juries before whom mining cases have been considered that it has there become an unwritten law that there are no extra-lateral rights, no matter what the patents pretend to convey.

Take next the copper mines. How many of those developed within the past 15 years conform to the idea of the law of 1872? Not Ely, nor Bingham (although in both places there are also found true veins), nor Ray, nor Chino, nor Miami. And here again the owners of the mines have found it necessary by mutual agreements to set aside the apex provisions of the law. But my point is here simply that all these great mines present features which place them entirely outside the category of deposits contemplated by Congress at the time the present law was enacted. And if the northern States of the Mississippi basin had not been excepted from the operation of this law, then we might have had the copper-bearing amygdaloids and conglomerates of Michigan, the iron-ore beds of Michigan, Wisconsin, and Minnesota, and the galena-bearing limestone strata of Missouri and Kansas also locatable as mining claims. Indeed, they are

[1] Snyder on Mines, Ed. 1902, vol. i, pp. 66 to 1668.

just as truly veins and lodes as many deposits now being worked in the mining States. What a harvest that would have afforded for mining lawyers and expert witnesses! The entire Mesabi range, 180 miles in length, might have been claimed as a single lode by a very few locators on the outcrop, starting with geologist H. H. Eames, who did actually file mining locations on it at Prairie River falls in 1866. Of course, there has never been an apex suit in Michigan, Wisconsin, or Minnesota. Such a thing is impossible. But there would have been an epidemic of them if wise previous legislation, giving the mineral lands to the States, and wise later legislation, explicitly excepting them from the operation of the Federal law, had not prevented that disaster.

Reason Number Two

The second objection to the present law is that it discourages prospecting and the discovery and development of new mines. This is, perhaps, the most serious charge that can be brought against it. Indeed, if proved, it is alone sufficient to justify the demand for revision. Traversing again ground already covered in this connection elsewhere, let us for a moment consider the changes that have come about in the West during the past 40 years. In the 60's and 70's there were but imperfect maps; no geological surveys, no published records or data competent as guides for the prospector. The great West was boundless and inexhaustible and mysterious and alluring. It contained mines of wealth untold, and anybody could find one by diligent search. So, with his pick, prospector's pan, and pack train, the pioneer searcher for fortune betook himself into the heart of the wilderness. And wherever some one, luckier, sharper of vision or more industrious than his fellows, chanced upon an outcrop, there he made his location, and to that spot was promptly followed by scores of others. And they, turning over the soil or working the golden gravels or trenching the surface débris, also found outcropping ledges and staked out their locations; and a camp was established. And when so many gathered together in one camp that rules for their conduct were needed, including public recognition of the individual's right to the fruits of his discovery, then a meeting was held, a mining district was organized, and rules were adopted; and these rules had the force of law. The mines were in their infancy, depth had not been attained, and the only definite feature of many a claim was the outcropping lode or "discovery." In that way, and for that reason, a discovery was made the *sine qua non* of a valid location, and this provision, universally adopted by the mining districts, was incorporated into the laws of 1866 and 1872. It worked well for a time. Mines, or at least veins, were easily discovered; and until a prospector had found one he seldom cared to stake a claim. But soon it was found that value attached to quartz locations in the vicinity of good

mines, even without a discovered vein, and many locations were made on barren country rock. Moreover, the land-office officials were complaisant, and had no means for ascertaining the truth or falsity of the affidavits of discovery; and often claims were patented upon a showing of the expenditure of the required amount in development work, although no vein had ever been discovered. As the West became settled and threaded with railroads, two changes of gradual development accomplished results of startling and vital importance to the miner. In the first place, it became exceedingly difficult to find any more outcropping lodes. All the typical quartz veins carrying gold, silver, etc., were located—at least, all those whose "iron hats" compelled attention. No longer could a prospector and his "pardner" with a burro and a two-month grub-stake find half a dozen promising ledges, and sell their locations for a year's wage. In the second place, Uncle Sam woke up and said the law requires a discovery of valuable mineral in place, and a mining claim is not valid until it is found; and began sending out inspectors and special agents and forestry-bureau employees and others to ascertain the character of these discoveries. And for a time, a good long time too, the prospector was looked upon as an interloper, a rogue, a land thief, who was presumed to be guilty of perjury until he proved his good faith. Unable to stand against these two discouraging obstacles, the increasing difficulty of finding unlocated lodes, and the expense of defending contests brought against him by relays of government agents, the prospector threw up his hands and practically disappeared, either went out of business or moved to some more salubrious clime, where inspectors cease from troubling and the weary none contest.

Lest my statements as to the fundamental necessity for a discovery before the completing of a valid location be questioned, it may be well to quote a few court opinions on that point.

In a recent decision the Supreme Court of the United States uses the following language:

> "While the statute does not prescribe what is necessary to constitute a discovery under the mining laws of the United States, it is essential that it give reasonable evidence of the fact either that there is a vein or lode carrying precious minerals, or if it be claimed as placer ground, that it is valuable for such mining, and when there is not enough in what the locator claims to have seen to justify a prudent person in the expenditure of money and labor in exploitation, this court will not overthrow a finding of the lower court that there was no discovery. It is the policy of the Government to favor the development of mines of gold and silver and other minerals, and every facility is afforded for that purpose, but it exacts a faithful compliance with the conditions required. There must be a discovery of mineral and a sufficient exploration of the ground to show this fact beyond question. If the lands contain gold or other valuable deposits in loose earth, sand or gravel, which can be secured with profit, that fact will satisfy the demand of the Government as to the character of the land as placer ground."[2]

[2] *Mining and Scientific Press*, vol. cvii, No. 15, p. 597 (Oct. 11, 1913).

The Supreme Court of the United States in Erhardt vs. Boaro, 113 U. S., 527–536, has given us an interpretation of this provision as follows;

"A mere posting of a notice on a ridge of rocks cropping out of the earth or on other ground, that the poster has located thereon a mining claim, without any discovery or knowledge on his part of the existence of metal there, or in its immediate vicinity, would be justly treated as a mere speculative proceeding and would not of itself initiate any right. There must be something beyond a mere guess on the part of the miner to authorize him to make a location which will exclude others from the ground, such as the discovery of the presence of the precious minerals in it, or in such proximity to it as to justify a reasonable belief in their existence. Then protection will be afforded to the locator to make the necessary excavations and prepare the proper certificate for record."

Again in Chrisman vs. Miller, 197 U. S., 313–323:

"There must be such a discovery of mineral as gives reasonable evidence of the fact either that there is a vein or lode carrying the precious mineral, or if it be claimed as placer ground, that it is valuable for such mining."

In Waskey vs. Hammer, 223 U. S., 85–90, a placer case, the U. S. Supreme Court, on Jan. 22, 1912, held:

"The mining laws . . . . make the discovery of mineral 'within the limits of the claim' a prerequisite to the location of a claim, whether lode or placer, the purpose being to reward the discoverer and to prevent the location of land not found to be mineral."

The order of grant is not: Free occupancy for exploration and then minerals if you find them; but is: Free minerals that have been found, and then possession with the right to appropriate them. This is conclusively shown by the decision of the U. S. Supreme Court in the case of Belk vs. Meagher, 104 U. S., 284, wherein the court said:

"The right to the possession comes only from a valid location. Consequently, if there is no location there can be no possession under it. Location does not necessarily follow from possession, but possession from location."

Upon this point we have the language of former Secretary Fisher, as follows:

"It is becoming increasingly evident that the lode law needs changes in one respect, at least. The law at present does not provide for the creation of any rights in supposedly mineral land, except by the issuance of patents, and in that regard congress has provided that a patent can follow only on a legal location and has said 'but no location of a mining claim shall be made until the discovery of the vein or lode within the limits of the claim located.' As long as congress desires to adhere to the policy at present embodied in statute law of disposing of mineral land absolutely, the law quoted above tends fairly well to the development of mineral properties where the ore can be discovered at or near the surface of the ground, but it seems to be ill calculated for a district where, as is the case notably in some of the copper mining districts, the ore lies at depths of hundreds and sometimes thousands of feet. The expense of actual discovery of the vein or lode within the limits of any particular claim in such cases involves deep exploration, either by drilling or by the sinking of a shaft from

the surface, or the extension of a tunnel into the claim. Either of these operations may involve great expense, and it has been repeatedly urged on the department that investors are reluctant to spend the money required without further assurance than the law as it reads at present can give them. On this ground the department has been strenuously pressed to so construe the law as not to require an actual discovery of the lode which is supposed to exist within each claim, but to patent the claims upon evidence of the existence of mineral at or near the surface wholly disconnected with the supposed lodes below and of no value in itself, either present or prospective, it having been further urged that in these cases it was a matter of geological inference that ore bodies did exist far below the surface.

"It is obviously the duty of the department to carry into effect the intention of congress expressed in statutory form. Congress having said that no lode claim should be patented without discovery of the vein or lode, within the limits of the claim, it would be an evident usurpation of power for this department to patent lode mining claims without proof of actual discovery. The frequently repeated assertions that the recent rulings of the department have overturned interpretations placed upon the law for 30 years seem utterly without foundation, as is pointed out in the recent departmental decisions. On the contrary, had the department decided that it could dispense with actual discovery it would have overturned the practically unanimous holdings both of the courts and of the department ever since the enactment of the lode-mining law. Doubtless in some cases claims have been patented where there was little or no proof of actual discovery, but the patenting of such claims is evidently to be laid to a misapprehension of the facts by employes of the land office, and not to a misconstruction of law by the department.

"It seems, however, possible by a change in the law to keep in force the policy of the government expressed in the mining law of rewarding the actual discoverer of valuable veins, while at the same time giving such protection during the work preliminary to actual discovery as would make it possible for capital to invest, taking no more risk than that inherent in the question whether there is or is not in fact valuable mineral in the place where it is sought. I suggest that the law should be amended so as to give a prospector, for a term of years, an exclusive right of possession and of prospecting within a limited area of land. In case actual discovery were made within the time given, patent would issue. The prospector should be obliged to perform a reasonable amount of work during the existence of the permit in order to make evident his good faith in attempting to find mineral within the limits of the claim. He should, however, be given the right by proper proceedings, to settle disputed questions of intervening claims, both in case of conflict with other mineral claims and also cases of conflict with agricultural claimants, so that he might at the earliest possible moment know whether or not his title would be absolutely clear upon his making discovery."

Some of the State courts have carried this discovery requirement to a surprising but perhaps logical extreme. Thus the Supreme Court of Montana holds, in Butte Consolidated Mining Co. vs. Samuel Barker, Jr., 35 Mont., 327, that

"The only way the locator of a quartz lode mining claim can manifest his intention to claim the ground embraced within his boundaries in good faith under the mining laws is by means either of a discovery shaft or a cross-cut sunk or made from an opening upon the claim sought to be located and not upon ground over which he has not complete control as a matter of right or from which he may be excluded at any time at the option of another."

What a contrast this presents to the laws of many countries where

the discoverer of valuable minerals, even upon privately owned land, is entitled to work the mines, in some cases sharing with the landlord, and in others merely compensating him for any damages done to the surface. Is our law an encouragement to prospectors?

The discovery of mineral deposits is no longer an incident of a summer vacation. The prospector of the future must possess more expensive equipment, greater technical knowledge, and a larger exchequer, and his operations must perforce be conducted through shafts, tunnels, and drill holes, in some instances taking years of diligent and well-directed effort. The requirement of a discovery before location and antecedent to the granting of any exclusive possessory title is therefore not only irksome and deterrent of results in practice, but wrong in principle.

The laws of most countries recognize the fact that ore deposits are subterranean and in many cases only to be found by digging, and in thus reversing the natural order of things we are conspicuously alone.

Reason Number Three

The next feature of our present mining law to be criticised is the almost universally condemned "apex" or "extra-lateral" right by which the miner is allowed to follow his vein beneath the surface of land owned by another. This has been already mentioned incidentally, but merits further special consideration. Its unpopularity is shown by the fact that of the replies in the nature of votes upon this question submitted in response to letters of inquiry sent out by the Committee on Mining Law of the Mining and Metallurgical Society of America, less than 5 per cent. were in favor of its retention. A few expressions of opinion by men competent to bear testimony, published in the *Bulletin of the Mining and Metallurgical Society* and elsewhere, are as follows:

George J. Bancroft.—"I think the extra lateral right principle should be done away with."

Robert N. Bell (State Mine Inspector, Boise, Idaho).—"I would advocate the abolition of the abortive extralateral right principle for all future mineral locations. The planes should be vertical and boundaries absolute."

Eliot Blackwelder.—"As to the extralateral rights principle, it seems to me inherently bad. In view of the difficulty of tracing many geological structures underground, and the still greater difficulty of predicting them in advance of actual mine work, I cannot see how this principle can fail to be a fruitful source of dispute and litigation in all but the simplest districts."

Juan Felix Brandes.—"The apex law should be discarded and boundaries made vertical."

R. W. Brightstocke.—"I never had any sympathy for the extralateral rights principle on account of the difficulties in regard to settlement, of which we have had ample records."

R. B. Brinsmade.—"Extralateral rights should be abolished."

R. W. Brock, Director of the Canadian Geological Survey, says: "I do not think

the extralateral principle should be retained. It was tried in Canada and was abandoned."

D. W. Brunton, former President of this Institute and of the American Mining Congress, in his presidential address to the latter uses the following language:

"It is a most unusual thing for a mine to find its way into the producing stage without having to fight one or more 'apex' lawsuits, and all because our legislatures in 1872 gave us the most archaic law that was ever placed on the statute books. No other nation possesses such an antiquated, absurd, and irrational mining law, which, no matter what it was intended to do, has only resulted in a continued expense and annoyance to mine owners and big fees to lawyers and experts. . . . One of the most disastrous effects of this continuous litigation is to frighten capitalists away from mining investments, because observing Eastern investors have learned that the discovery of a new mine carrying rich ore is almost certain to be the beginning of the most expensive and interminable litigation."[3]

Alexander Burrell.—"I am in favor of eliminating the absurd practice of attempting to dispose of dips, spurs and angles for mining claims. There should be no extralateral rights."

Geo. E. Collins, President of the Colorado Scientific Society, says: "The extralateral right principle should be abolished, excepting in areas where it exists already."

W. L. Cumings.—"No extralateral rights in any case should be sanctioned by law."

Thomas L. Darby.—"The extralateral rights principle should not be continued in any future locations of mineral lands."

Algernon Del Mar.—"If the present system of alienation is continued, we should abolish the extralateral rights, and make all mining claims conform to the rectangular boundaries projected vertically downward; but no existing rights should be put in jeopardy."

Francis Drake says: "Every effort should be made to do away with the extralateral rights principle. . . . All boundaries should be vertical."

E. E. Ellis.—"If the present system of alienation of title is retained the system of vertical boundaries to claims should undoubtedly be adopted."

N. H. Emmons says: "Under no condition should the extralateral rights principle be retained in any law of the United States."

J. R. Finlay says: "The principle of granting extralateral rights should be abolished."

H. C. Ferguson, recently of the Mining Bureau of the Philippine Islands, says: "I believe there can be no question that the extralateral right has been a source of endless litigation and uncertainty, and that even if nothing more is done, its abolition would be a great step in advance."

Jno. C. Fleschhutz.—"The extralateral right should be discontinued."

Ernest Le Neve Foster says: "I am utterly opposed to the extralateral rights principle, having been intimately connected with its working since 1872 and intimately mixed as an expert in a large amount of the litigation caused by it in the State of Colorado. Its effect to my mind is that it is a source of litigation, blackmail and quibbling, and often results in unfair verdicts by juries."

R. W. Hadden says: "I do not believe in the extralateral right. It has been the cause of untold litigation, and has caused great hardships both to the original locator on an apex, and a *bona fide* locator of a claim bordering the side lines of the apex claim."

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[3] *Mining and Scientific Press*, vol. cvii, No. 21, p. 815 (Nov. 22, 1913).

H. C. Hoover pithily remarks:[4] "Lest the Americans think that the apex law was a sin original to themselves, we may mention that it was made use of in Europe a few centuries before Agricola, who will be found to set it forth with great precision."

E. B. Howell says: "I am opposed to the doctrine of extralateral rights. It would be all right if mineral veins maintained their identity and continuity with depth, but they do not, and the inevitable result is litigation."

Murray Innes.—"Extralateral rights benefit lawyers only and should be promptly done away with."

C. E. Jamison.—"It is my opinion, in which I believe the great majority of the people of Wyoming concur, that the present mining laws should be revived somewhat along the following lines:

"(A) Doing away with extralateral rights, although recognizing all rights previously conferred, etc."

Frederic Keffer.—"To abolish one fruitful cause of mining litigation, and to render it possible for the most unlearned man, without the aid of courts or lawyers, to know what was his and what the other man's, I would do away absolutely with the extralateral rights."

J. F. Kemp.—"Practically everyone familiar with the uncertainties and difficulties of the present laws involving apex rights to lode claims, must have a profound conviction of their unsatisfactory nature and must be desirous of seeing future locations made upon a different basis."

Alfred C. Lane.—"The extralateral rights principle should not be retained."

Francis C. Lincoln.—"Extralateral rights should be abolished and vertical side lines substituted."

Henry Louis.—"Mineral concessions should in every case be rectangles of a suitable size, and mineral rights should be bounded by vertical planes; I can see no justification for the law of the apex and extralateral rights."

Hugh F. Marriott.—"In the future all boundaries should be vertical without any exception whatever."

Walter McDermott.—"Extralateral rights are based on a supposed regularity of deposits which does not exist in nature. All the experience of the United States is directly opposed to it in practice; it is unworkable and has had to be dodged by agreements, by local rulings of courts, or by death of litigants."

Philip N. Moore.—"The extralateral rights principle should not be retained in any circumstances."

Henry S. Munroe.—"I believe that the extralateral right should be omitted from all sales of mineral land in the future and that provision should be made for the extinguishment of all existing extralateral rights by condemnation proceedings, even should this require a constitutional amendment, unless such rights are utilized within a definite period of years from the date of the passage of the new law."

E. E. Olcott.—"I should most unequalifiedly suggest the abandonment of the extralateral rights principle in every possible form it may have assumed heretofore. It has been one of the greatest nuisances in the American mining law, and I believe was originally implanted in that law with the idea of creating strife and friction and business for certain classes of professional men."

R. W. Raymond.—"Apart from the mischievous extralateral right, the greatest cause of confusion and waste in those mining districts of this country which have been afflicted by our mineral land law, has been the lack of public surveys."

M. L. Requa.—"Extralateral rights should be abolished."

L. D. Ricketts.—"I thoroughly believe in giving a right to the mineral only vertically underneath the surface area claimed."

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[4] Translation of Agricola's *De Re Metallica,* p. 83.

F. L. Sizer.—"By all means, the square location, with limiting vertical planes through all lines, should be adopted and the menace of extralateral rights litigation forever disposed of, so far as future grants are concerned."

Geo. Otis Smith, Director of the U. S. Geological Survey, says:[5] "This law has proven more productive of expensive litigation than of economical mining, and in many of the more recently established and more progressive mining districts has been made inoperative either by common agreement or by compromise between adjoining owners."

Warren D. Smith.—"I think our present mining law in the United States is about as out-of-date and crude an affair as any public statute I have seen. It must have been framed either by farmers or lawyers, as no sane mining man would perpetrate such a thing on an innocent country."

Benjamin B. Thayer.—"The mining claim, instead of being 1,500 ft. in length by 600 ft. in width, shall be 1,500 ft. square, the underground boundaries to be determined by vertical planes projected through the side lines."

R. H. Toll.—"In any case I believe in vertical boundaries."

Arthur H. Wethey.—"The extralateral rights principle has been a most fruitful source of litigation. In future patents it would be well to increase the area of quartz claims and restrict ownership to the mineral beneath the surface."

Montana Society of Engineers, Butte, Mont.—"We would recommend that the area of mining claims be increased, and that the ownership of the mineral be limited by vertical end and side planes."

John E. Hardman.—"To keep the extralateral right any longer in the statute books of the United States would be a crime; in my personal opinion, and in consequence of my Colorado experience, I regard the insertion of the maintenance of the extralateral rights principle a blot on the civilization of the United States and I have no hesitation whatsoever in saying that *that* feature of the American law should be abolished absolutely and forever."

F. A. Ross.—"But most important of all is the 'square location'—*without extralateral rights*—by which is removed the most fruitful source of United States mining litigation and its attendant evils."

Maurice Codwell.—"The apex difficulties do not, of course, come up in Mexico, and it would seem that the system followed in that country is better in every way than that demanded by the United States Government."

Kirby Thomas.—"I believe that the Mexican system of locating by *pertenencias,* 100 meters square, with no extralateral rights, is satisfactory, and better than the American system of apex."

J. F. W. Murdoch.—"Not being a lawyer nor a 'mining expert,' I believe that extralateral rights ought to be abolished."

A. Montgomery (State Mining Engineer of Western Australia, Perth, W. A.).—"The lateral rights principle obtaining in portions of the United States is a standing marvel to the rest of the world, and that it could be seriously proposed to perpetuate it outside of cases in which it has unfortunately been already granted seems incredible to most outside engineers with whom I have come in contact."

George W. Riter.—"Elliott Lord says that during the first seven years on the Comstock Lode, twelve leading companies were involved in 245 law suits, nearly all of which were over the right of possession. (Comstock Mining and Miners; *Monograph IV, U. S. Geological Survey,* 1883, p. 177). On a smaller scale, every other mining region goes through a similar experience whenever rich ore is found."

Frederick F. Sharpless.—"Vertical boundaries should be adopted and the extralateral rights principle abandoned."

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[5] *Thirty-second Annual Report, U. S. Geological Survey,* p. 15 (1911).

An occasional word is spoken in favor of the apex law. Its supporters are not numerous. They can be divided into three classes: first, those who are not familiar with its working by actual experience, or who speak without careful reflection; second, those who believe that, although it has been the source of trouble and expense in the past, yet there is but little likelihood of such annoyance in the future, that all controverted cases have been litigated and all doubtful questions settled by court decisions, or that the mines have all been found and it is not worth while to make a change at this late day; third, those who are by nature conservative and fearful of any changes, who perhaps recognize the evils of the present, but fear any revision will be for the worse. To these three classes the following remarks are addressed:

(1) It must not be supposed that the parties to apex litigation are the only ones to suffer from it. They pay the immediate and physical costs; and when the bills are presented, they heartily condemn the law which makes such litigation possible. But not all the mines are affected by such trouble all the time, and hope springs eternal, and even the defeated recover their spirits and are sooner or later willing to take another chance. But the fact is that the whole mining industry pays the bill. There is a factor of hazard and loss and expense of uncertain dimensions hanging over every mining investment wherever the apex law is in force. No attorney or mining engineer can safely recommend the purchase of a quartz mine in the West without taking it into consideration. Indeed, the more he knows about mining lawsuits, the larger the factor of safety which he demands on this account. Hence, consciously or unconsciously, the whole business of mining is hampered and forced to carry the burden of this dangerous provision of our present law.

(2) While it is true that the U. S. Supreme Court has handed down decisions which definitely settle some of the principles of apex law, it is very far from true to state that no other vitally important questions remain undetermined. There are points upon which the U. S. Courts of Appeal in different circuits are in direct conflict. There are questions involved in litigation now pending which have never been passed upon by the Supreme Court, and some of these questions contain possibilities which one shudders to contemplate. I may merely mention one as an example. The law provides for the location of mining claims in such a way that the side lines shall be parallel to the outcrop of the discovery vein and not more than 300 ft. distant from it. Many thousands of claims have been located and patented in which the discovery vein crosses the side lines instead of the end lines, and in such cases the courts have decided that the end lines become side lines. Now, in the case of a claim 1,500 ft. in length whose discovery vein crosses the side lines, and whose located side lines therefore become end lines and whose located end lines become side lines, it may be 750 ft. or more from the

apex to the actual side lines. In other words, the patentee, by misrepresenting (innocently perhaps) the relation of his surface lines to the outcrop of his discovery vein, has obtained a patent from the United States Land Office for more land than it was authorized to convey. Is such a title good? Some of our best mining attorneys question it seriously. The question is now before the Federal Court in Utah, and if the decision is against the validity of such patents, the title to valuable claims in every mining camp in the West will at once be shaken.

To the second portion of the second class, those who do not look for the discovery of more mines, we would say that Uncle Sam still controls about 623,000,000 acres of his original farm of less than two billion acres, and that the man who has doubts as to the existence of as many mines upon this remaining one-third as were found upon either of the other one-thirds, must lack confidence in the destiny of the American nation. That the mines have not yet been discovered is no proof of their non-existence; that they are not to be found so easily and rapidly is probably a blessing in disguise, if we once revise our laws so as to make their discovery possible and put their exploitation in harmony with the principles of economy.

(3) With the third class we have to deal in all human affairs. They are typical of the Chinese during the past thousand years, rather than of up-to-date progressive citizens of these United States. Their views are always entitled to a hearing, but when reforms are widely called for, the stand-patter must stand aside or be run down by the chariot of progress.

One rule of the apex law of great importance to the miner in working beneath the surface, and yet one with which the majority of mining engineers do not seem to be familiar, is stated by Judge Lindley as follows:

> "In following his vein downward the apex proprietor must keep within it. He cannot crosscut underneath another's surface to reach the vein."[6]

In this respect our apex law is not so good as its German prototype of the sixteenth and seventeenth centuries, which gave to the locator an inclined location with bounding planes parallel to the vein some 25 or 30 ft. from it on both foot- and hanging-walls.

Violations of this rule are frequent, and it is sometimes broken by common consent; but it is occasionally invoked to the great surprise and expense of the miner, who thinks that because the government patent granted him extra-lateral rights, which he may perchance have still further established by costly court proceedings, he is consequently empowered to crosscut from his own shaft on various levels through his neighbor's ground for the purpose of mining his own vein.[7]

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[6] Lindley on Mines, 2d ed., p. 1111, Sec. 615.

[7] See *Engineering and Mining Journal*, Mar., 1913.

Other arguments against the apex law will probably be presented in this symposium and other testimony might be procured almost without limit for its condemnation. There can be no question that the sentiment of a large majority of men engaged in actual mining is strongly opposed to its perpetuation in our statutes.

Reason Number Four

Another defect in our present law to which the attention of Congress has frequently been invited is the lack of any provision for appeals to the courts from the decisions of land-office officials. It is contrary to the general spirit of our institutions and an anomaly in constitutional government to take away from any citizen property rights to which he considers himself justly entitled under the law, by the mere fiat of an appointed government official who is here to-day and gone to-morrow. To place in the hands of such officers the final dicta in matters involving property valued at hundreds of thousands of dollars, and to provide no method of appeal to any duly constituted, permanent, non-political, judicial tribunal, is not only to subject the said officials to severe and unnecessary tests of moral courage and fidelity, but to require in them the qualifications of superior judges and experience in the weighing and interpretation of the law, which many of them cannot be expected to possess. Serious injustice is often done without any remedy at law to the defeated applicant.

The records of the land-office decisions are full of instances of this fact. One of the most recent is what is known as the Yard decision. Four or five years ago the Department of the Interior held that the Land Department might cancel mining claims before application was made for patent, alleging that the discovery is not sufficient, or that the land is held for speculation, or for any other sufficient reason. Now, although it might be claimed that this decision was unjust and *ultra vires*, yet there was no method of taking an appeal to the courts, for they have no jurisdiction over Land Office decisions. In another case, that of J. P. Nichols and Cy Smith, the same question has just arisen, and the former decision is squarely reversed, the present First Assistant Secretary remarking that the decision rendered in 1909 in the Yard case is entirely indefensible, whether viewed from an administrative or a legal standpoint, and that to the extent that such decisions might mislead citizens or officers of the government "into an unwarranted invasion of private rights, it would be repugnant to good administration as subversive of law."[8]

The Secretary further used the following language:

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[8] *Mining and Scientific Press*, vol. cvii, No. 23, p. 879 (Dec. 6, 1913).

"While the title to land remains in the United States, and controversies arise between occupants thereof, whether agricultural or mineral, neither party having invoked the jurisdiction of the land department for the purpose of acquiring the ultimate title, the courts have the power to determine their rights, based upon the law of possession, and all other questions necessarily involved."

The statement of the Secretary, while no doubt strictly accurate as between two mineral locators and so long as the mineral character of the land is not called into question, is with difficulty harmonized by a layman with the language of Mr. Justice Brewer in Burfenning vs. C., M. & St. P. Ry., U. S. Rep. 163, p. 323, as follows:

"It has undoubtedly been affirmed over and over again that in the administration of the public land system of the United States questions of fact are for the consideration and judgment of the Land Department and that its judgment thereon is final. Whether, for instance, a certain tract is swamp land or not, saline land or not, mineral land or not, presents a question of fact not resting on record, dependent on oral testimony; and it cannot be doubted that the decision of the Land Department, one way or the other, in reference to these questions is conclusive and not open to re-litigation in the courts, except in those cases of fraud, etc., which permit any determination to be re-examined."

This instance is only mentioned because of its timeliness and to illustrate my point as to the desirability of giving to some courts the power of review which Justice Brewer says they have not now.

The celebrated Cunningham coal cases in Alaska are another concrete instance of maladministration of justice and the infliction of obloquy and financial loss upon perfectly reputable and law-abiding citizens by the dicta of political appointees, who were forced by the stress of political expediency to render decisions justified by neither the law nor the evidence, and from which there is no recourse. In the interests of justice, provision should be made for appeals in important cases, and perhaps in all cases, from decisions of the Commissioner of the General Land Office or of the Secretary of the Interior to some court of competent standing and jurisdiction, whose decisions could and would be accepted by the public and the interested parties with confidence in their just and correct interpretation of statutes. The enactment of such legislation was specially recommended to Congress in a Presidential message by William H. Taft, but it failed of passage, largely through the misguided opposition of the chief apostle of conservation. It should be brought up again, and insistently, until placed upon our statutes.

Reason Number Five

Another very important reform which has been more or less agitated, and is certain to attract the attention of Congress in the near future, is in the coal and petroleum laws. Although of different geological habit and physical structure and mode of treatment, and therefore each

deserving of separate legislation, coal and petroleum are here mentioned together because they are both mineral fuels and both inadequately provided for in existing statutes. Volumes could be written and hours spent in rhapsodizing over our matchless supplies of coal and oil and moralizing over the question of their benefit to that portion of the human race which inhabits the United States of America and its possessions. But such considerations are stayed by the reflection that a ton of coal and a barrel of oil are of no benefit to any one until they are burned, and that coal mines and oil wells are essential to the carrying on of industry, traffic, commerce, and manufacturing as they exist to-day, and that it is for our best economic interest to mine and use every ounce of carbonaceous fuel that can be profitably and efficiently employed in useful endeavor.

The law authorizing the location of coal land reads as follows:

"Every person above the age of twenty-one years, who is a citizen of the United States, or who has declared his intention to become such, or any association of persons severally qualified as above, shall, upon application to the register of the proper land office, have the right to enter, by legal subdivisions, any quantity of vacant coal-lands of the United States not otherwise appropriated or reserved by competent authority, not exceeding one hundred and sixty acres to such individual person, or three hundred and twenty acres to such association, upon payment to the receiver of not less than ten dollars per acre for such lands, where the same shall be situated more than fifteen miles from any completed railroad, and not less than twenty dollars per acre for such lands as shall be within fifteen miles of such road.

"Any person or association of persons severally qualified, as above provided, who have opened and improved, or shall hereafter open and improve, any coal mine or mines upon the public lands, and shall be in actual possession of the same, shall be entitled to a preference-right of entry, under the preceding section, of the mines so opened and improved: *Provided*, that when any association of not less than four persons, severally qualified as above provided, shall have expended not less than five thousand dollars in working and improving any such mine or mines, such association may enter not exceeding six hundred and forty acres, including such mining improvements. . . . . .

"The three preceding sections shall be held to authorize only one entry by the same person or association of persons; and no association of persons any member of which shall have taken the benefit of such sections, either as an individual or as a member of any other association, shall enter or hold any other lands under the provisions thereof; and no member of any association which shall have taken the benefit of such sections shall enter or hold any other lands under their provisions."[9]

Any mining engineer knows that the development and equipment of a coal mine is an undertaking so expensive that it is not safe to make the outlay needed unless a supply of coal is assured for many years. The limitations placed by the law upon the amount of coal land that may be located by an individual or by an association are therefore either foolish or futile. As a matter of fact, the lack of harmony between the law of Congress and the inflexible law governing economic conditions has led to attempts to evade the former, which have not always been such

[9] Snyder on Mines, vol. ii, pp. 1259, 1260, 1261.

as would pass a creditable examination under the searchlight of modern investigation. The matter is at present in a transitory stage. Coal lands are for sale, in limited areas, under the law, at appraised valuations. The probable solution will be the passage of a bill reserving coal lands from sale, but authorizing the Secretary of the Interior to lease them under terms to fit the conditions in each case, and under the supervision of the Bureau of Mines.

There has been much difference of opinion as to whether petroleum and natural gas are minerals.[10] The courts, with few exceptions, have held that these substances are minerals and locatable as such. The Land Department has been on both sides of the question; but the matter is finally set at rest by the Act of Congress which reads as follows: "Any person authorized to enter lands under the mining laws of the United States may enter or obtain patent to lands containing petroleum or other mineral oil, and chiefly valuable therefor, under the provisions of the laws relating to placer and mineral claims." (Act approved Feb. 11, 1897, 29 Stat. at Large, 526.)

Being locatable under the placer Act they are subject to the requirement of a "discovery" before a location can be perfected, and since, as already explained, the law gives no exclusive possessory right to the prospector while he is searching for mineral (except of the spot where he is actually at work, *pedis possessio*) there have been numerous instances where two or more outfits have been drilling on the same tract of land, each trying to make the first strike of oil and thus secure possession, and bloodshed has not infrequently been the outcome of this feature of our senile law. In the interests of peace and for the preservation of oil which might otherwise have been wasted, as well as to protect the Federal land reserves, the oil lands have been withdrawn by Presidential order under the authority of Congress. Legislation is needed, but the situation is not serious, and there is ample time in which to make a thorough study of the entire question and thus prepare to meet conditions undreamt of when the present laws were framed.

Reason Number Six

There are still other substances which should be provided for, and which were either not known to exist or not considered as valuable minerals in 1872. Among these substances we may mention radium-bearing minerals, phosphates, potash and other salts, rare earths and similar products, all of which are likely to prove of increasing importance and value in the future, and for whose location and exploitation careful provision should be made in our laws.

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[10] Snyder on Mines, vol. i, p. 284.

The present Secretary of the Interior in his recent report, speaking of this subject, says:

"Some years since this department announced the discovery within the United States of a deposit of potash which it was hoped would render our farmers independent, for a time at least, of all other sources. This deposit still lies unused. No proper laws have been passed by which it can be put into use. A common-sense view of the matter would be to treat these lands as it has been suggested we should treat coal lands.

"So, too, should our vast deposits of phosphate rock be brought into the world's supply. We are giving a constantly increasing volume of thought to the scientific methods by which the fertility of our soils may be increased. And the time is likely to come when the deposited phosphorus in our western lands will be regarded as of almost priceless worth. Few appreciate how extensive these deposits are. They run for hundreds of miles through Wyoming, Utah, Montana and Idaho, and in other States similar deposits of lesser extent are known to exist. We have millions of acres of phosphate lands which are estimated to contain several billion tons of phosphate rock; undoubtedly the world's largest known reserve."[11]

Reason Number Seven

From the very first the law has been defective in not requiring notice of mining claims to be filed with the general Land Office or some duly constituted Federal officer. Uncle Sam has been a very careless custodian of the property of his wards.

"Indeed, the United States government does not to-day possess either records or maps showing what portions of its public mineral lands have been appropriated by valid mining-locations, and, being held under possessory title, do not now belong to that domain."[12]

Such carelessness in our national book keeping has led to much confusion and the infliction of unnecessary expense and hardship upon those whom the laws were intended to benefit. Thus, for example, while with one hand the government gave to the prospector the right to those mines which might be found, with the other it handed out land grants to aid in the construction of railroads to the Pacific and thus facilitate the operation of the mines. It said to the railway companies, "You may file your selections with the Commissioner of my Land Office in Washington;" and to the prospector it said, "You may file notice of your mining location with any county clerk. We don't care to be bothered with such details." So the prospector and the railway company filed on the same land, and for years each thought his title unclouded. The prospector spent months of labor and all his cash, and finally sold to a mining company. The railway company sold the land to a lumber company, and spent a million dollars in constructing a road to market the lumber cut by the

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[11] *Engineering and Mining Journal*, vol. xcvii, No. 1, p. 29 (Jan. 3, 1914).

[12] R. W. Raymond: Discussion of Canadian Mining Law, by J. M. Clark, *Trans.*, xlii, 617 (1911).

lumber company. Then the government got around to surveying the townships, and the railroad and the mining company both asked for patents, and for the first time was discovered a conflict which had existed for 10 or 15 years, and which never could have arisen if our laws had been good. The mining company said to the railway company, "You have no right to mineral land." The railway company replied, "I only wanted the timber and that was rightfully mine, but I don't believe the land is any good for mining anyhow." Then the government sends the experts of the Geological Survey to investigate and report; and their report is to the effect that general geological conditions are similar to those of some other district where good ore is found, therefore it is mineral land, and must be stricken from the railway company's selections; but, as a matter of fact, there has been no discovery of ore in place as required by the mining law, and therefore it cannot be patented to the mining company. And this is no idle dream, but a picture of situations actually existing under our chaotic mining law.

Reason Number Eight

The law at present provides a limit to the time within which patented quartz claims may be attacked for fraud or irregularity of location, but makes no such provision for patented placer claims. Known veins within placer locations must be declared and paid for separately or else they are excepted from the placer patent and can be located by others in lode claims. All veins on placer ground not known to exist at the time application is made for patent belong to the grantee, but without extra-lateral rights. If an applicant for placer patent can be shown to have had knowledge of the existence of a valuable lode within his lines prior to the making of his patent application, and to have concealed that knowledge, his title as to that vein is subject to cancellation at any time upon the making of proof thereof in court by a contesting locator. There is no limit to the time for such contests, and they are still being brought, in some cases 25 years after placer patent. The law is very defective on this point, for it frequently happens that veins discovered to-day have a value by reason of improved metallurgical processes or transportation facilities which they did not have at the time when the placer claim was located and patented. The owner of such a claim is sometimes put to the expense and annoyance of defending such contests repeatedly, each time at the risk of an adverse verdict, since there is no limit to the number of contestants. The law should provide the same protection for placer as for lode claims in this respect.

Reason Number Nine

The present statutes are defective also in permitting the location of an unlimited number of quartz claims in any district, and in not requiring

actual and useful development. Many promising mining claims and even entire districts have been smothered for years by this practice. Much has been said and written about it, and every old timer knows that the assessment work on thousands of claims which for a quarter of a century have been thus held (and by the other familiar trick of re-location of each other's claims at the end of the year on a sort of community basis), has often amounted to no more work of actual exploration than could be done by a couple of able-bodied single jackers in three months' time. And any one who has bought mining claims in the older camps of the West can testify that he has often paid considerable sums for locations of this sort, although the physical condition of the property was in itself incontestable proof that the claims were at that very moment open to re-location, or could be successfully contested at much less expense.

Conclusion

There are many other minor defects in our mining laws; but it is believed that the foregoing presentation of the case will be sufficient to serve as a text for those who feel that something is wrong, but do not know just where the trouble lies. Moreover, if we are unable to convince Congress of the need for revision by showing them the worst of the rottenness, they will hardly be moved to action by fly-specks and an occasional worm-hole. If they desire to legislate in the interest of a large and important industry and by aiding it benefit the entire nation, they will give heed to an appeal from the representatives of that industry. Personally, I believe that the subject is one of great importance and that its proper solution is through the recommendations of a commission appointed by authority of Congress for the study of the entire question and the drafting of a new mining code, after investigation of conditions and the desires of mining men in all parts of the country.

Discussion

Hennen Jennings, Washington, D. C.—I have been so long out of the country that I have not had an opportunity for getting any mining company into title difficulties, or urging new laws, or giving any expert advice upon the subject of the laws of the apex; so I can make my statement very dispassionately and impartially.

I was connected with mining in South Africa some 16 years, and thus had an opportunity to become acquainted with the mining laws of the Transvaal under the Boer government.

I was greatly impressed with the main principle of these laws: namely, the conveying of certainty of title. All claims were held on the basis of a surface area pegged out, and with the downward continuance in accordance with vertical-plane projections of the boundary lines.

There were two classes of claims, known as digger's and prospector's. They were held under a leasing system of payment of so much a month, but no limitation was made as to time of holding so long as the necessary payments were made. The payment for digger's license was larger than for the prospector's, the higher price being for ground that was under exploitation. One person could peg off but a limited area; but there were no laws preventing amalgamation of claims, which was done on a big scale; but greedy and speculative holding of claims was minimized by the constant necessity of paying licenses for all claims held, whether worked or not.

It is true that in this way most of the claims got into the hands of strong corporations, but it is also true that the original locators had a good chance to sell at a good price, and the nature of the deposit was such that it required a great capital outlay to profitably equip and work a mine.

From what I have heard and read, it would appear that the law of the apex was framed to a large extent by the prospectors of California and Nevada, who no doubt believed it was a system that was advantageous to themselves.

Now, has this really been the case? How many of the prospectors who pegged out the ground have worked their claims to a finish, and benefited by the extra-lateral rights given under this law? Have not litigation and uncertainty of title been detrimental features in selling out to capitalists? Have the capitalists benefited as a whole by these rights when the many and costly lawsuits are taken into consideration?

I want to know also, whether the public has benefited by this law, and what has been its influence upon morality in mining. Has it not had the tendency to lower the moral tone, by making secrecy almost a necessity, and to tempt the honest man to make location on a very flimsy basis in order to guard against blackmail?

Who, then, has it helped? Possibly a few professional mining experts may have obtained remunerative employment, but the best of them have at the same time decried the law. I believe it has benefited the blackmailer and the faker; and the lawyer has not lost by it.

In Europe an American mine that has not gone through the fiery furnace of a lawsuit is considered a risky possession.

Thus it would seem that even to the original locators and first holders, the law has been something of a boomerang.

Sidney J. Jennings, New York, N. Y.—There is one point I would like to bring out. We have heard a great deal about apex. We have not heard so much about the definition as to what is a vein, and that is a point with which I have had some considerable experience in my work in the United States.

You would think that a definition of a vein was a reasonably easy

thing, but in a case in which I was interested, not as a witness nor as an expert, but simply as a worker of the property after it had been acquired by a favorable decision, this matter was up.

A fissure was found on the surface carrying mineral in payable quantities. It was followed down, and at a certain horizon ore was found to make on a bed of limestone. The location of the fissure on the surface was held by one individual, and the location of the apex of the favorable bed of limestone was held by another individual. Then the question was, which was the vein, the limestone bed, or the fissure where the ore was originally discovered and followed down? This was fought for many years, and the decision of the Supreme Court was made to the effect that the limestone was the vein, as it was the place where large bodies of ore were always found. There were numerous fissures going through this bed of limestone, and wherever those fissures got into the limestone large payable bodies of ore were found, consequently the limestone and not the fissures was the apex. That strikes me as ingenious, but it is difficult to predicate how far some other ingenious theory may carry another individual in upholding what he supposes to be his right under the extra-lateral theory.

I am of the opinion that, as Dr. Raymond said, it is wise to concentrate your opposition on one point. If you have a concerted attack on one point it is not apt to be overthrown, whereas if you have a scattering attack against various wrongs, you cannot make as big an impression. But there are so many points which, while not as objectionable as the apex right, are as well worthy of being changed, that I would be inclined to include in our opposition one or two other features mentioned by Mr. Winchell in his paper, rather than restrict ourselves entirely to the attempt to persuade the law makers to do away with the apex theory.

Hennen Jennings.—In the Transvaal companies were formed on the dip, one behind the other, and called deep civil companies. You would think that there would be great dissatisfaction among the first people who pegged out claims when the deposit went out of their boundaries. As a matter of fact, this was not the case, for although they would have been glad to have had a greater length of line, there was no bitterness of feeling on this score either among corporations or individuals, as they knew their rights and risks at the start. There were no lawsuits or ill feeling, as has been the case with the apex law. I do not think the deep levels would be developed to-day as they have been if held only by the companies that first started.

It would have lessened the progress of development, and caused uncertainty and litigation. Our legislators seem to fear that by limiting downward rights, they are injuring the original locators. It is not so, if you give them at first latitude to peg out liberally and as much as their

resources will allow them to work. The extra-lateral right stopped mining instead of helping.

GEORGE OTIS SMITH, Washington, D. C.—It may seem presumptuous to add anything to what Mr. Winchell has said about the reasons for revision; but I would suggest reason No. 10, as it has occurred to many of us, and as it was suggested to me by C. B. Dutton, of the Bureau of Mines, namely: That we have confusion worse confounded by reason of the fact that the States and the local districts have added to the Federal codes their special State laws and district regulations, so that the result of some of these has been really to obstruct what might be expected as the favorable operation of the Federal law.

HORACE V. WINCHELL.—When you come to the consideration of the question of a single, definite reform, laying all emphasis on the one particular revision desired, you will find it so interlocked with other provisions of the law as to make it almost impossible. You spoke of abolishing the apex law, and so you must give a wider piece of land. Senator Smoot introduced a bill providing for the abolition of the extra-lateral right. What would have been the result? You cannot abolish the extra-lateral right without abolishing the right of discovery. They are all tied up together. The only way is to investigate the whole field, and frame a harmonious and consistent theory of mineral law, and then try to get it enacted. You want to get a theory which will give the prospector the security of a possessory title while looking after his mineral, and unquestioned, undoubted rights afterward.

Why should it be a matter of question as to what a prospector or miner is entitled to? If he knows he has what is immediately under the surface, everybody knows it. But as it is to-day, there is trouble, doubt, question about it; questions of uncertainty, hesitation, and the consequent lack of development. We all know that something is the matter with prospecting. We all know that mines will not live forever. We know we are exhausting our mines at a tremendous rate. The United States, with a population of 6 per cent. of the people of the globe, occupying 6 per cent. of the land area, produces 30 per cent. of its minerals. Now we cannot keep that up unless we continue to find mines, and we cannot find mines unless mining titles are made secure.

JAMES KIRKPATRICK,* Dillon, Mont. (communication to the Secretary†).—Many people will be glad to see better laws enacted and will hope for speedy results. That the prospector is an important individual and that he naturally has much to contend against goes without saying. In his discoveries he should be safeguarded to the utmost from the rapacity and greed of those who are ever ready and watchful to take advantage

* Non-member. † Received Feb. 10, 1914.

of his omissions or neglect. The ordinary requirements of mining law seem sufficiently burdensome to his pioneering spirit and he is usually unable and unwilling to fight a legal duel against heavy odds. The result is too apparent for comment.

It is probable that half or more of the present unpatented mining claims in this State are subject to re-location because of inaccuracy of measurement in their boundary lines. The average prospector is under the impression that, should his boundary lines extend beyond legal allowance, he runs no risk but will have the privilege, if necessary, of diminishing them; but the court has held in at least two instances (Hauswirth *vs.* Butcher, *Montana Reports*, vol. iv, p. 299; and Leveridge *vs.* Hennessy, *Pacific Reporter*, Nov., 1913, p. 907), that more than a slight over-measurement of boundary lines voids the location. Thus, if the locator of a Montana lode claim, through inability or ignorance, fails in accuracy of measurement, his claim, regardless of time or money expended, is exposed to the cupidity of any shark. It has come to be common practice for the big fish thus to gobble up the little ones. Justice as well as regard for the welfare of the mining industry of this State dictates that, in case of excess, the locator should still be protected in the amount of ground contemplated by the mineral-land laws.

Claims are frequently located in difficult, even almost inaccessible, places where, without assistance or facilities for measurement, the locator is obliged to approximate his directions and distances and, even in favorable localities, cannot always procure a rope, or afford to employ a surveyor.

It is to be hoped that the mining societies, congresses, and committees will succeed in impressing upon the Congress of the United States the necessity and importance of at once revising our moss-grown mining laws. The results of the efforts will certainly be watched with great interest throughout the West.

E. B. Howell,* Butte, Mont. (communication to the Secretary†).—I do not believe in the extra-lateral rights doctrine any more then do mining engineers generally, but prospectors usually do, and if you try to effect too revolutionary changes in this respect you are sure to fail.

I would make the following suggestions:

1. Abolish the distinction between quartz and placer claims by making the government price for each $5 per acre. This will terminate the present "known lode" infirmity of placer titles. Any mineral land that is worth locating at all is worth $5 per acre. The price of land, paid to the government, is a mere bagatelle in the cost of mining, anyway. There was never any good reason for making placer land only one-half as much as lode claims and to make the price uniform will result in simplification of mining law.

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* Non-member. † Received Feb. 10, 1914.

2. Make all claims 600 by 1,500 ft. in maximum dimensions and make no limitations as to how the claim must lie with reference to the apex of the vein, and restrict mining operations to the vertical planes of the boundaries. In other words, if a prospector is sure his vein pitches south he can lay his claim so that the apex will lie just inside his northerly side line. Or if he wants to be sure of more of the vein on the dip let him turn his claim at right angles to the apex, letting the outcrop be close to one end line. In this way he can have nearly 1,500 ft. horizontally within which to pursue his vein.

3. There should be uniform provisions as to the method of locating, marking boundaries, and recording claims. I think we have the best law relating to these topics in the State of Montana. The Federal law makes no requirement relative to the marking, except that the claim must be so marked upon the ground that its boundaries can be readily traced. The Montana law specifies, as *prima facie* evidence that the claim is so marked, the placing at each of its corners of some one of several prescribed forms of monument—for instance, a post 4 by 4 in. in size and 4 ft. 6 in. long, set one foot in ground, with mound, etc. A post firmly set with a mound of rock about it makes the best corner; but it should be remembered that in some mining districts of the West it would be very difficult for a prospector to secure posts. Hence, alternative methods of marking should be provided. Where posts of a smaller size than those prescribed in Montana are used, it becomes a question for the jury as to whether the claim is so marked upon the ground that its boundaries can be readily traced, but the locator does not necessarily lose his claim.

4. I would abolish the present method of locating quarter-sections of placer land by associations of individuals. That is unnecessary for legitimate placer mining operations. My observation has been that such locations are made by seven-eighths dummy locators and one-eighth land grabbers. If placer claims are 600 by 1,500 ft. in size they can be laid along the channel of the stream—which is quite necessary for placer operations.

5. There ought to be something done to prevent corporations from going into new districts and locating all the land solidly with claims having common end and side lines. I have known of this being done in some instances. It is a perversion of the spirit of the mining law, which might be prevented by prescribing that no locator shall, either by himself or through the agency of any other person, locate more than, say, two claims within a radius of one mile of his primary discovery.

I think that these suggestions, if followed, will result in a simplification of the law without any revolutionary changes. In some respects it would resemble the present law in the Philippine Islands.

The Segregation and Classification of the Natural Resources of the Public Domain

BY FREDERICK F. SHARPLESS, WESTBURY, L. I., N. Y.

(New York Meeting, February, 1914)

THE term "segregation," as here used, means the separation of certain natural resources into groups, consisting of one or more members, with the idea that when thus segregated, each group may be more easily and effectively administrated. We may, for example, consider surface rights as distinct from underground rights, and stop there; or we may go further, and deal separately with timber, water, and agricultural rights, or, going underground, we might deal separately with such groups as precious and base metals, clay, oil, gas, etc. The present paper contemplates only the separation so far as practicable, for administrative purposes, of surface from mineral rights.

"Classification," in this paper, has reference to the groups into which the government has divided, is dividing, or will hereafter divide its natural resources; first, into the broad classes of mineral and agricultural lands; and, second, into coal, oil, phosphate, brine lands, etc., the central idea being the separation into natural groups for the purpose of simplifying administration and for the purpose of encouraging maximum development and minimum waste.

The two subjects are in some respects quite distinct, but as my argument develops, I think it will be obvious why they are discussed in the same paper.

In the pursuit of our professions as mining engineers, geologists, or operators, we are continually confronted by conditions with which our present mining laws or regulations are incompatible. It may be a conflict, hardship or injustice, a piece of favoritism, or of unnecessary red tape; or we may see lack of development in a promising locality, and wonder what is the reason. Often we can see where a modification, slight or radical, in the laws would have obviated the difficulty without doing harm to any of those immediately concerned. Such alterations as individuals could intelligently suggest would be based on a relatively small number of situations occurring in their experiences. The published replies to the queries formulated by the various committees on mining law appear generally to reflect personal experience. Concerning a few points, there is a marked uniformity of opinion, while on other points opinions

appear to be almost irreconcilable—simply due to the fact that individual experiences and observation must be rather limited and not because of irreconcilable differences.

The object of altering our present laws is not to compound a panacea for all the ills to which mining is susceptible. There are certain changes which, because of their obvious advantages, we may be able to procure; the necessity of other changes is less obvious, and respecting these there is little probability of securing new enactments. Nevertheless, those of us who believe that the latter are right and proper, should give our testimony in their favor, and show all of the weakness that we believe exists, even though we know that our suggestions will, for the present, receive little consideration. The greatest good for the greatest number is the end for which we must all strive; and in giving our approval to one recommendation and withholding it from another, we should try to view the question as broadly as possible, and not be influenced to too great an extent by our own personal experience and desires.

It is of prime importance in connection with the subject of mining law to arrive at the fundamental conception of proprietorship of the natural resources of the public domain.

In the early days of mining, all mineral rights were held by the Crown, not only for the purpose of securing the precious metals for coinage, and for the "dignity of the Crown," but also that others than owners of surface rights might be encouraged to work underground, that underground resources might not lie idle because of surface occupation. Later, and up to the present time, various enlightened peoples have held that, for one reason or another, the fee of mineral land should remain in the State or central government.

Our Federal government has, from time to time, taken title to the major portion of the lands, outside of the thirteen original States, as trustee for all citizens of the United States, with the object of administering the trust to their best advantage. There is nothing in the original grants or in subsequent enactments to indicate that there was or ever had been any intention of retaining the fee of mineral lands, timber rights, water rights or other resources in the government or in the people. There was nothing in the trust requiring or preventing alienation. The prime object was that the natural resources of this immense area be used to the best advantage of all of its citizens. Generous grants were made to various States for various purposes, and the lands so granted passed entirely from Federal control and became subject to State legislation. Some States, in recent years, have forgotten whence they had their origin, and have expressed resentment at the Federal control of lands within their boundaries, not remembering that the government lands are lands belonging to the citizens of the United States and not to the citizens of any particular State.

I think it will be generally admitted that the owners of public lands and rights are the citizens of the country, and it is the business of the government to segregate, classify, sell or lease these lands as, in its wisdom, may seem most advantageous for all citizens.

In the administration of natural resources, we must bear in mind some important differences. Mineral rights and surface rights bear quite different relations to society. Surface rights have a permanent, underground rights but a transient value. The more intensely a farmer cultivates his land, the more valuable does it become to him and to the community. If development takes the shape of permanent and useful structures on the land, the increase in value to the individual and to the State may reach vast proportions. Indeed, it is not possible to anticipate the maximum usefulness which surface rights may acquire; but we know that when these rights are being used to the best advantage the country is also reaping the greatest benefit, and it is then that the life of the right appears longest and most useful.

A mineral right is of a different nature. The more it is worked, the smaller becomes its intrinsic value. It is of value to the community only at the time, and in proportion to the extent of its productiveness; but the greater this temporary usefulness, the shorter its duration.

The agricultural claimant locates a "homestead," while the prospector locates a "claim." The former indicates permanency of tenure, while the latter suggests a temporary possession.

A difference in the nature of agricultural and mineral land was recognized by Congress, when it passed an Act in 1879 calling for the classification of the public lands by the U. S. Geological Survey.

The output from a mineral right is, in many cases, a public necessity. The output from surface rights is much less liable to be so. The output of a mineral property being transient, the public has but a temporary interest in its development. The resources of the surface being permanent, the public will always have an interest in them.

The owner of a mineral right should receive every encouragement to develop his resource, to use it, and get out of the way, while the owner of the surface should be given every encouragement to make his improvements permanent and of ever-increasing value.

We do not all see the distinction between the ownership of the surface and of that which lies below the surface; but the arguments of those who do not see the difference dwell more upon the feasibility of regarding them as identical than they do upon proof that they are identical. We have, in this country, been regarding them as identical for so long that many of us believe that they are inseparable, and it is this belief, rather than any real difficulty, that stands in the way of segregating surface from underground rights.

If it is true that there is a marked difference in the nature of the rights

referred to, then the government, in assigning those rights, should not confound them. It should treat them separately, safeguarding fully the interest of the new and the old owner. It has been found in other countries, and will be found in this, that with surface rights segregated from mineral rights, regulations may be enforced with greater ease, with less inconvenience to the interested parties and with increased usefulness of the rights to the community at large, than when grantees hold all rights within the boundaries of their concessions.

In the early days of our history, we were rich in undeveloped resources, lands, minerals, water, and timber, beyond any possible requirement then apparent. We were rich in everything except population; and we gave liberally of all rights, without conditions, in order to secure this population. There appeared to be no reason for withholding, even temporarily, any of our resources. It was a natural policy to adopt, and one that has resulted in a marvelous development within an incredibly short time. Whether it has produced the greatest good for the greatest number, over the greatest time, is questionable; but that it fulfilled the requirements of the period is beyond doubt.

Suggestions have been made, to the effect that laws under which this marvelous development has taken place should not be modified, lest we hinder the rapid march of progress. Surely we do not want to curb progress, that must be farthest from our thoughts; but progress at the price of prodigality cannot go on forever.

Conditions have changed and are changing rapidly; some policies that were in force 20 to 50 years ago are not applicable to present conditions. Fundamental alterations are forcing us to change our views as to what policies are best. The signs of the times are pointing in new directions.

In order that progress may not be halted, we must change our laws and keep open a field for the uninterrupted exercise of the energies of the coming generation, giving it, so far as we are able, opportunities equal to those that have been given in the past.

One of the changed conditions to which I refer is, that a very large proportion of the public domain has already passed from the control of the Federal government, and the area over which the prospector may roam is becoming more and more confined. Both prospector and agricultural claimant must now do considerable searching to find a desirable locality. We are approaching the conditions of some of the older countries, where the governments no longer hold title to any considerable area of surface rights, but where, owing to the existence of that antiquated policy of segregation, the Crown or the government still holds some mineral rights of importance.

The first paragraph of the Prospectus, so familiar to all of us:

"The surface of this district has barely been scratched."

is growing further from the truth every year. The "unscratched" districts are very scarce, and if the policies of the past are to be continued, it will not be many years before we have given title to all of the good "scratching" ground, and the day of the prospector will have passed.

For several years, we have been discussing the cause of the decline and fall of the prospector; and the most potent reason for this decline appears to be the lack of a good country in which to prospect. We have deeded immense tracts to railroads, upon which the prospector has no right to go; we have deeded wide areas to agricultural claimants and we have deeded mining lands with prodigality, until we have left only those lands classed as mineral-bearing, yet devoid of such outcrops as once made the life of the prospector an interesting and exciting existence, if not always a profitable one. Generally, there has been no provision in the railway land grants whereby the Federal government would have any further interest in the grants, if in the course of time they proved to be more valuable for mineral than agricultural purposes; and it has been the same with the lands granted to individuals under agricultural patents.

Not only has there been an actual change in conditions, but the public mind is changing; we are looking at things from a different point of view than that of 50 years ago. What seemed to us right and proper then, may seem questionable to-day. The signs of the times point toward Federal restriction, if not toward Federal control.

For a long time, personal ambition, initiative, and accomplishment have gone unbridled until excesses have been committed that trespass on the rights of society. It is to curb these excesses that it has been proposed to place one industry after another under government control, with a tendency toward socialism. The pendulum swinging from extreme freedom of the individual or corporation on one side to socialism on the other, will probably come to rest at a point where business is conducted under certain governmental restrictions. However much some of us may regret to see "interference or competition" by the government, as Dr. Raymond puts it, it is probably here to stay; and the sooner we adapt ourselves and our laws to the changed views, the better off will we be.

Was the policy of those who have gone before us so bad? And have we done properly in alienating ourselves so completely from our patrimony both surface and underground? I believe that, under the circumstances, the policies adopted and followed for so many years were good. A mistake was corrected when the Homestead Act of 1862 was passed. After that date, the policy of providing public revenue from the disposal of the public domain was abandoned. That many other mistakes were made is absolutely certain; particularly is this true in regard to the development of our mineral resources. In those days, there were few people and fewer railways; both were needed; there was neither time nor money for careful investigation.

It was not intended, when deeding lands to the railways as a bonus for construction, that the mineral resources of the country should be tied up; indeed, it was not intended that any title should be given to mineral lands. That was an accident, a mistake. The same may be said of all agricultural patents that have been given to corporations or to individuals. The development of the mineral resources of those lands was simply overlooked in the broader necessity of getting a population upon arable lands and means of transportation to enable that population to become self-supporting and add to the prosperity of the country.

Going back still further, to the lands of the Mississippi valley; the grantors of the fees to the timber areas of Minnesota, or the agricultural lands of Wisconsin, Missouri, and Oklahoma, while they might have fully realized that they were deeding mineral rights, certainly could not have thought of this feature seriously, or more consideration would have been given to those rights, in which the whole of the American people were interested.

I think it may be regarded as a very serious mistake to have deeded, for a few dollars, lands that are to-day worth hundreds or thousands of dollars per acre.

Those lands were deeded for the use that could be made of their surface rights; and any enhancement due to efforts of an owner was a legitimate gain to him and to his heirs, but when through an accident, pure and simple, that owner found himself rich, with something that he did not buy or create by his own efforts, when he found himself possessed of something of value that did not belong to him, but did belong to the people and which the people did not intend to give him, then most certainly a mistake was made.

The mistake was not that of failing to classify lands properly, and deed only agricultural, mineral, or timber rights. Such a classification would have been impossible at that time; for even with the strides that have been made in geology during the last 50 to 75 years, it is still impossible to classify accurately. Even to-day, in those very districts cited, with a tremendous amount of underground knowledge available, no geologist can say, pending actual development, exactly what areas will be more valuable for mineral than for agricultural products.

The big mistake was in not inserting in deeds to surface rights a clause to the effect that if and when mineral discoveries should be made, the public interest in those minerals should be preserved. No provision was made for utilizing underground rights to the best advantage for the common good; they must lie idle until, in the wisdom of those who never bought them, they might be developed to their owner's personal advantage.

There were other mistakes made, some of them perhaps more serious than the one mentioned, but they have not to do with the subject of this

paper and will not be considered here. The mistakes of the past cannot be rectified, and if we go on alienating surface and mineral rights in the same manner, many of them will be repeated in the future. From time to time, enactments and regulations have been adopted to remedy previous defects; but they have not been as radical as conditions warranted. In order that we may not continue to repeat the mistake referred to, the logical thing to do would be to segregate the surface from underground rights and treat them as the two distinct resources that they are, alienating the one or the other as it may be sought for commercial development.

If this is not done, then more than ever do we need a careful classification of our lands not only into timber, agricultural, and mineral lands, but a further refinement into the kind of mineral, as coal, oil, phosphate, iron, precious metals, etc., and however far such classification is carried, we can see that, in all probability, a case will soon arise in which it has not been carried far enough.

We know to-day that it would be advantageous to have all of our coal, oil, gas, and brine lands classed separately, that we might apply different regulations to them; but in spite of our advanced geological knowledge, we cannot tell beyond question what areas are going to produce any one of these substances and what may produce two or more of them. We cannot even tell with any degree of accuracy what areas may or may not come under the broad class of mineral-bearing, let alone a subdivision of the minerals. Where then will a further attempt at classification lead us?

The classification that has been done by agents of the government has been well done. With a vast unknown area to map and classify, and limited means with which to accomplish it, the amount of work done has been remarkable; and we wonder, not at the mistakes, but at the remarkable accuracy that has been shown.

It would seem that in advance of actual discovery our geologists and the government would be attempting the impossible in striving to classify further than has already been done on the unoccupied areas of the public domain, and yet the necessity of varying regulations to suit the varying mineral conditions is obvious.

Can any better work be done in the future than has been done in the past? Yes, undoubtedly; but in many cases it will still be unsatisfactory. The doubtful areas will remain subject to doubt until actual discovery is made, and there will be many cases where absolutely unthought-of minerals will be found in unsuspected places.

If I am correct in the assertion that it was the intention of the Federal government to hold the public domain as a trust for the benefit of all of our people; if our forefathers were correct in separating mineral from non-mineral bearing lands; and if I am correct in stating that an exact

classification is impracticable, if not impossible, what may be done to harmonize these three propositions? It must be something to protect the public interest in lands; it must protect the holder of mineral rights and surface rights; and it must permit us to adapt different regulations to different natural products. That something has as its foundation the segregation of mineral rights from surface rights. Whether we do that or not, we must certainly classify various mineral rights for administrative purposes. The necessity of classification is so obvious as scarcely to require argument or proof; our present laws require it and conditions demand it. What is being done and what has been done in the way of classification is admirably set forth in *Bulletin* No. 537 of the U. S. Geological Survey, issued in 1913, which shows also the aims and objects of classification and the necessity of carrying this procedure to far greater lengths than have yet been attempted.

In March, 1879, Congress passed a law doing away with the Territorial surveys and establishing the U. S. Geological Survey. This enactment provided for the classification of the public lands and for geological examination of the public mineral resources. Classification, under this law, into mineral, agricultural, and timber lands began as soon as appropriations were available for the purpose, and continued on the same lines up to 1906, when, through instructions issued from the Department of the Interior, a broader interpretation was given to the original enactment, and classification was begun with the object of facilitating the administration of public lands.

Quoting from *Bulletin* No. 537, previously referred to:

> "It is apparent, although it has nowhere been expressly stated by Congress, that the fundamental principle guiding that body has been to dispose of each tract of the public domain for the use to which it is best adapted. Thus the laws have provided that agricultural entry should not be made upon valuable mineral lands, that lands containing deposits of coal should be sold only as coal lands, and so on for all other classes of land."

In pursuance of this idea, withdrawals from the public domain have been made from time to time, to be again restored to entry when the lands have been properly classified, or regulations have been adopted under which the mineral rights may be developed. In most of these classifications, the land has been denominated coal, oil, phosphate, agricultural, or forest land, each parcel being placed under that class for which it seemed best adapted.

It was not until a comparatively recent time that any segregation of surface from mineral rights was made; but this has now been done with both coal and phosphate lands. Agricultural claimants may take up the surface rights in certain districts without acquiring rights to any of the coal or phosphate lying under them.

The complete classification of the public lands is a stupendous under-

taking. Up to the present time, only the most urgent cases have received the attention that they require. If the classification is to be followed to its logical conclusion, there will be work for the Geological Survey for many years to come, so long as there are any natural resources that have not been alienated by the government. The ideal plan would be to have every district properly and minutely classified before any of the resources were disposed of, and preferably before they were applied for. This, of course, is a practical impossibility. Indeed some one of the resources of a tract may not be known until after another is exhausted, and it is utterly impossible for any geologist, chemist, or engineer to look into the future far enough to provide for what may ultimately be found. The government has never made any provision for a complete classification of the public domain. It would be a very heavy expense and one of questionable propriety for several reasons; but if we could have such a classification with a flexible arrangement permitting of alterations as knowledge increased, it would be of immense value in the administration of the public domain.

At the time any piece of land is applied for, one of its resources will no doubt have been recognized; but that all of its possibilities have been foreseen is improbable. When one useful resource is recognized, and applied for, it is neither fair nor right that the applicant be given that for which he has no use and for which he does not care; it is not fair that the granting of rights be held up pending an indefinite period of investigation of those resources for which the applicant has neither desire nor need; nor is it right that the government be put to the expense of investigating resources that are not asked for.

To give the applicant that which he wants as early as he wants it, to avoid classification expense by the government at a time when it is not absolutely needed, and to conserve the rights of the people—all this may be accomplished simply by segregating the rights into certain groups and disposing immediately, under appropriate laws, of the right asked for.

An objection that is offered to classification is that it is regarded as impracticable, and instances are referred to where, in the past, certain lands were classed as agricultural that are now known to be mineral, and are not open to prospecting. Rather than an argument against classification, I take it that this really is a strong argument for more careful classification in the future. Those using the above argument are opposing segregation also; and yet had segregation been in vogue at the time these lands were patented, the complaint now made would have no existence.

Segregation of mineral rights would injure the farmer, the timber owner, and perhaps the town-lot owner, in that it might take away from him his rights in something that he had not paid for, was not expecting, or

was procuring by fraud. But so long as he is entirely protected in what he did buy, his rights are not comparable with those that should be reserved for the miner or one who is willing to risk a stake to see what is under the surface. It is useless to classify now, and expect such classification to hold; we must have something flexible through which we can make adjustments as occasions arise.

It is noted that many of those who argue against leasing, classification, or segregation, and in favor of alienation of everything, say: "Let there be a proper classification and then stick by that classification." But, they do not say how we are to make a proper classification to-day, and to-day is when it is needed. To-day we cannot tell with positiveness what minerals will some day be found. If we could, I think that the most of us would join in saying "classify properly and then stick by that classification, selling or leasing," but as we cannot classify for all time to come, let us segregate the surface rights from the mineral rights, and when one after another valuable mineral is found, we can apply appropriate legislation.

The present agitation with regard to radium is much to the point. It is proposed to withdraw all public lands from locations that are supposed to contain radio-active elements. In view of our present very limited knowledge of this element and its associates, I think such withdrawals are going rather far. This will certainly not encourage prospecting in the public domain; and if radio-active elements are as valuable as we hope they are, the one thing that we want to encourage is the prospecting for them. It is suggested that the government will do the prospecting. With all faith in the U. S. Geological Survey, and with all due respect to it, I do not think we should call on the Survey to do our prospecting. Let the regulation come in the production, or sale, or exportation of the product, but do not tell the prospector that he must not hunt for the element. Here again the remedy is the segregation of surface from mineral rights. Let the surface go for agricultural or other purposes; if gold is found let that go too; or if iron or coal, let them be operated under regulations applying to those substances; and if radium is found let regulations be applied to suit the emergency; but do not withdraw the land from entry for those purposes for which we know that it is useful. Just how far it may be advisable to go with segregation at the present time, is a question; but the work that has been done by the government in this direction has been so satisfactory that it certainly is practicable to go much further.

Owing to the fact that agricultural rights have been interfered with by the withdrawal policy of the government, and because it is extremely unfortunate to interfere with agricultural settlement when there is any demand for the land, certain segregation or separation acts have been passed, covering, however, certain lands only. The first Act, March, 1909, provides for the case of a settler who has selected for agri-

cultural purposes non-mineral land which is reported later to be coal land. The settler may acquire title to the surface only, and be entitled to recover damages if the surface is damaged or the farm interfered with by subsequent mining operations—the title to the coal, of course, remaining in the government.

The second Act, that of June 22, 1910, permits agricultural entries on land already classed as coal land. The agricultural entry is, of course, for surface rights only. A third Act, of Aug. 24, 1912, permits the filing of agricultural claims over certain areas in Utah already classified by the government as oil or gas land.

Bills have been introduced extending this principle to lands in other States than Utah and to phosphate lands in Idaho.

Thus, in a very few cases, the government is segregating surface from underground rights with the object of permitting the surface to be used just as soon as any one wants it, and permitting this without alienating its rights to the unknown mineral resources below the surface.

Quoting from Secretary Fisher:

> "The law at present does not provide for the creation of any rights in supposedly mineral land, except by the issuance of patents, and in that regard Congress has provided that a patent can follow only on a legal location and has said, 'but no location of a mining claim shall be made until the discovery of the vein or lode within the limits of the claim located."

Because of this difficulty of securing title to deep-seated deposits, a certain area in Arizona was withdrawn in September, 1912, from any but mineral entry. This tract is one on which no mineral outcrops, but which members of the Geological Survey regard as favorable for the existence of deep-seated copper deposits. This land will be held by the government pending such discovery. In the meantime, the surface can be used for no other purpose. By segregating, the surface could be used for any purpose whatever and the mineral title held back until there was sufficient reason for doing the deep work.

Under the existing laws, the locator of a placer claim secures his rights under conditions far from satisfactory. He must make affidavit that there is no vein or lode within the claim, also that it is not taken up for the purpose of controlling water or for the use of timber. And when he has sworn to these exceptions and secures his patent, he is liable to lose his title at any time because some one else believes that fraud has been committed.

A valuable vein may be discovered; a contest is almost sure to be filed; and the innocent party is put to heavy expense, if he does not lose his property. Again a low-grade vein may be opened which because of local conditions is of no commercial importance. In the course of time, with improved transportation and better methods, this vein becomes a "commercial proposition," but the vein is not locatable because of previous

alienation of the surface and everything within the surface. It is a resource that has been lost to the prospector and to the public, and thus an injustice has been done in granting what was not asked for or paid for. Had the surface or placer rights been segregated from the vein rights, the original locator would have been free from litigation, and the public's interest in the resources not asked for would have been conserved.

If segregation were in force at the present time, early classification would not be so essential as we now consider it to be. We would not have to class large areas as coal, oil, phosphate, or salt lands, probably including in such classification many acres of no value for mining purposes, and omitting many acres valuable for the underground rights. We would simply give title to the surface; or, if it was the mineral constituent that was the main feature of value, the government could permit its exploitation under appropriate regulations for that particular substance. No agricultural or other lands would be held up for lack of classification; and the expense of an unnecessary or useless classification would be avoided.

With segregation in force, lands would classify themselves when minerals were discovered and would automatically subject themselves to the regulations belonging to their proper class. If new minerals are discovered, the value of which is at present unknown or uncertain, the government, not having disposed of its rights, will be in a position to formulate regulations that will encourage development and exploration. If our laws are based entirely on facts, eliminating all theories and opinions, we can certainly expect better results. Basing law on facts will prevent the issuance of titles where undeserved, and where fraud may be intended.

Alienation may or may not follow segregation. If surface rights are to be alienated, and few suggestions have been made to the contrary, segregation will simply hold title to mineral in abeyance until some one is ready to develop the mineral resources of the tract. Then this right too may be alienated if desired. In the event of a person acquiring title to a piece of land which he has reason to believe will some day, by reason of its geographical location, control an important industry and become very valuable, I thoroughly believe that he and his heirs or assigns are wholly entitled to the so-called unearned increment because of the man's foresight. Should he spend his fortune to develop this property, he is so much more entitled to the increased value. Regardless of the success or failure of his surface development, should it subsequently be discovered that he had located on a valuable diamond pipe, an important iron or fuel deposit, and that he had suddenly become wealthy because of this discovery, it must certainly be regarded as an unearned increment to which he has no just right.

In the mining and treatment of precious metals it is customary to use a great deal more surface than corresponds to the area underlain with

useful vein matter. The operator needs a place for his mining and milling plant, his tailings, and dwellings. Sometimes he requires additional surface because of the timber that grows upon it. In other words, when a man works a vein, he needs all the surface included in his claim and more too. From which it might be suggested that the surface rights should not be separated from underground rights in the case of precious metals, lead, copper, and zinc. In the past this need of surface rights has caused the prospector to locate much more ground than he really required, locating and holding it as mineral claims, doing no work to benefit its mineral possibilities, and really securing title to it through a technical fraud. Or if he has not done this, he has been forced to buy his neighbors' claims at mine prices, just to secure surface rights. Were the two kinds of rights separated, each and as much of each as was desired could be purchased or acquired without technical fraud, and often the desired surface rights could be more favorably located than if the prospector were allowed to take only those within the boundary of his mineral claim.

A very few objections have been offered to segregation. Of 61 mining men who have expressed an opinion on the subject, I note that 7 are undecided, 15 are opposed to it, and 39 are in favor of it. Very few of those who are opposed to segregation have given any reason except that they believe it impracticable; some suggest that there will be a confusion of ownership. Theoretically this may be the case. In practice it has been found that the owner of mineral rights has generally been able to acquire all surface rights required for construction and operating purposes, and generally these have been acquired direct from the surface owner more quickly and on better terms than by acting through the government, even though there existed government machinery for the purpose.

Some have contended that it is impossible to segregate all minerals from surface rights, taking as examples Mesabi iron ores, the Pennsylvania cement limestones, and the clay banks everywhere which may some day be mined for aluminum. That the mining of any one of these substances will involve the destruction of the surface over the body worked, must be admitted; but it does not follow that because of these exceptions we must always treat the surface and its underground resources as one and the same thing. If a man desires to mine iron ore or quarry limestone or slate, there is nothing in the segregation idea to prevent him from getting all of the land he wants.

If it is desired to allow ownership of land to include ownership of superficial non-metallic substances, as in Australia, this, it has been found, can be done without any complications whatever.

About all of the objections offered to segregation suggest that the objectors do not want to see a change made for fear that some unforeseen trouble may arise. But segregation is not an experiment. Mineral

rights, water rights, and timber rights have been recognized as distinct from agricultural rights in many lands, for many years. Canadian Provinces and Australian States have conducted their affairs under laws which did not segregate and did alienate, and they have also worked under laws where segregation was followed and lands were sold, or leased, or operated for the production of that with which nature had endowed them. Mismanagement has at various times attended the administration; but the tendency that has been most beneficial has been toward more governmental control, and not less. In these countries there will be no return to the practice of selling everything within given boundaries, regardless of what may be there, and for what it may be useful.

In nearly all of the Provinces of Canada, there are three distinct rights in every parcel of land, timber rights, mineral rights, and agricultural rights. In some instances these rights are all held by one individual or corporation; in others they are held by three different ownerships. The miner is at some disadvantage, for he is only entitled to cut such timber as he requires for his buildings; but he can buy stumpage at a nominal rate and does not go through the farcical scheme of making mineral locations and doing assessment work just to hold timber. Under the above arrangement, the miner, unless he buys surface and timber rights, does at times find himself in conflict with the timber and land owner, but it is not a serious conflict; and as the mineral is apt to be of greater temporary importance than the other rights, the miner appears to be somewhat favored.

In Australia, the segregation of surface from mineral rights has been the custom in most of the colonies for many years. There a person who has obtained title to a piece of land for cultivation, building, or other improvement, is presumed to have taken it up for that purpose only, and not for the unknown natural resources that it may ultimately prove to hold. The State does not reserve all values, such as the unearned increment due to some peculiar geographical position, proximity of railways or power plant, etc., nor does it retain surface deposits of clay, slate, lime, etc. These are conveyed with the surface rights.

In practical operation, it has been found easier and simpler to make an arrangement with the owner of surface rights to work on his ground than it has been to get that right through the government by any condemnation proceedings. The great advantage in Australia has been that it has thrown any and all land open to agricultural location without interfering with the rights of the prospector, both of which have been of prime importance in the development of that country. And the tendency is rather toward restricting the rights of the land owner, making conditions easier for the prospector of minerals.

While segregation of surface from mineral rights would not cure all existing difficulties connected with our present mining laws, it would,

because of the very different nature of these rights, simplify the application of remedies. The Federal government could encourage the development of the surface or of the underground portion, without sacrificing the interest of the public in that feature which is not to be immediately developed. The immediate necessity of classification with attending expense and uncertainty would be avoided, and the application of certain laws to certain classes of mineral substances could be deferred until the mineral was discovered. The regulation of surface and mineral rights could be enforced without serious conflict. In short, segregation will conserve our mineral resources for those who wish to develop them, and the lands will be held in such shape that appropriate laws may be enforced without detriment to those not interested in mining.

Discussion

R. W. Raymond, New York, N. Y.—The very clear and logical exposition of Mr. Sharpless is based on premises not yet established. It assumes, in the first place, that the legal purpose of the classification of public lands, as carried on hitherto, has been to fix their character accurately for purposes of *administration;* whereas, the so-called "mining law" of the United States is simply a set of rules for *selling* the public mineral lands, and has no more direct relation to mining than the agricultural land law has to agriculture. It creates particular classes of lands, such as mineral lands containing lodes, placers, salines, coal, petroleum, etc., and prescribes the way in which tracts of each class may be temporarily occupied, and ultimately purchased, and defines the nature of the title to be conveyed to the purchaser. Its purpose, like that of the agricultural-land law, is to transfer the public domain outright to its citizens, in such a way as to encourage private enterprise and discourage monopoly. Since it fixed different units of area, different forms of procedure, different limitations of tenure and title, and different prices per acre for these different classes of public lands, it was highly important for the exploring or investing citizen to know in which class the United States as land owner had placed the particular tract he desired, so that he might know the kind of title he could acquire, and by what method, under what conditions, and at what price. Obviously it would have been quite sufficient for this purpose if the United States had simply said "This we call mineral land, and will sell it under the mineral-land law. If you find it more or less valuable than the price you paid, that is your lookout. A bargain is a bargain." That is what an honest private land owner would have done. And a part of it is actually done by the United States. It requires of the mineral-land locator that he shall discover valuable deposits before acquiring title; but if it turns out afterward that the deposits were not valuable, so that the purchaser was deceived (as is actually the

case with the majority of mining claims patented hitherto), the United States does not dream of returning to him the cost of surveys and patent proceedings which he has sustained. In that case, a bargain is a bargain. But if a tract of supposed agricultural land, granted as such, turns out to be more valuable for mining, the United States tries to take away from its own grantee, on the ground of this later discovery, the title it has given him. An illustration may be found in the suits now pending against the Southern Pacific R. R. Co., attempting to annul the title of that company to certain lands granted to it, and of all the people who have purchased parts of such lands, on the ground that petroleum has lately been found in them, or so near them as to warrant the classing of them as petroleum lands. The basis of these suits is the provision in the grant to the railroad that it does not include mineral lands, and the claim that the mineral character of the land, no matter how, or how much later, established, should be held to vitiate the original grant. No doubt this proposition has plausible legal force, since nobody can deny that a thing explicitly reserved in a deed was never granted; and if mineral lands were thus reserved from railroad grants, the only defenses which the railroad company can now set up would seem to be (1) that petroleum is not a mineral, and hence that petroleum-bearing lands are not mineral lands; and (2) that, whatever be the value of the first defense, the word mineral, as used all over the Pacific slope, at the time when the grant was made, meant *ore*—*i.e.*, a solid, including mechanically, or in chemical combination, a valuable metal—and that, at that time, petroleum-bearing lands, though known to exist in California, as well as in Pennsylvania, etc., were never included among "mineral" lands. Upon the common-law principle, that a deed or contract expresses the mutual understanding of the parties, and must be construed according to that understanding, it may be, in my opinion, justly held that petroleum-bearing lands, not being regarded at the time of the grant as "mineral" lands, were not included in the aforesaid reservation. This I regard as a sufficient defense of the railroad company and its innocent grantees in the cases I have mentioned; but I think it is an outrage that, after forty-odd years of peaceful, *bona fide* possession, and after innumerable sales of so-called agricultural land to innocent purchasers, the original title given by the United States should be assailed on such grounds. Simple honesty, such as obtains between man and man, would require that the United States, as grantor of the land, should determine, before its sale, in what class it had decided to place it, and then stand by its own decision.

I could give many other illustrations, all carrying one moral—namely, that after all precautionary measures and forms have been duly complied with, the title to land, given by the United States, should be definite and indefeasible. The new policy, advocated by some, of perpetual government ownership of mineral rights, is not in question here. Even

the advocates of that policy must agree that, so long as the present system of selling mineral lands outright is continued, the government ought to give clear and final title to purchasers. For this purpose, it is relatively immaterial whether its "classification" be scientifically correct or not, if it only binds the government and protects its grantees.

In a word, the argument of Mr. Sharpless has noteworthy force only on the assumption that the United States is expected to administer its natural resources permanently as the property of the whole nation, and not to transfer them to private citizens or to the several States Concerning that policy, I have elsewhere expressed and supported my views in other contributions to the Institute.

The Location of Mining Claims Upon Indian Reservations

BY WILL L. CLARK, JEROME, ARIZ.

(New York Meeting, February, 1914)

HE who enters a mining claim within an Indian reservation of the United States of America acquires no rights thereby, because of the fact that the lands within such Indian reservation are not a part of the public domain, and cannot be located or acquired as mineral land. However, where such an entry is authorized as to a particular reservation by an Act of Congress, such claims as may be entered under such authorization are thereby segregated from the reservation, and the Indian title is extinguished.

Under the Choctaw Constitution, any citizen of that nation, in other words any Choctaw Indian, who discovered a coal mine, acquired an exclusive right to all coal within a radius of 1 mile.

The laws of the Chickasaw nation provided for the formation of corporations to develop coal and other mines, with authority to contract with others to develop and work the mines. Under these laws, leases were made; but Congress subsequently abrogated all existing leases, prohibited all persons from receiving royalties from such mines, and provided that all coal within the nation should remain the common property of the tribes. Such leases are now expressly prohibited by an Act of Congress (32 United States Statutes at Large, 655). All leases of mineral lands upon Indian reservations must now be made under regulations promulgated by the Secretary of the Interior, and the royalties must be paid into the United States Treasury for the benefit of the tribes.

In Canada the Indians have no rights to the royal mines and minerals, and the government can make no stipulation with the Indians which would affect the rights of the Province in which the lands are situated.

Therefore, while it is true that under our present law no rights can be acquired to a mining claim within an Indian reservation, it seems to be fully within the authority of Congress to make laws, giving such rights to mineral locators as it may deem necessary or expedient.

There is a demand for a general law that will permit mining upon Indian reservations, and I am informed that most of the members of both houses of Congress from the Western States are in favor of Congress pass-

ing a bill which will permit the working of mineral claims discovered upon Indian reservations.

The following letters from members of the Senate and House of Representatives are quoted in support of this assertion.

HOUSE OF REPRESENTATIVES,
WASHINGTON,
August 15, 1913.

"There is a great demand for a general law that will permit mining upon Indian reservations. As the law now is, the Secretary of the Interior cannot permit metal mining under any circumstances. It seems to me that a law should be passed authorizing financially responsible parties to enter the reservations for the purpose of mining upon the payment, in cash, of a small annual charge for each claim located, and whenever any bullion is produced, a royalty to be paid upon the same. This royalty ought to be equivalent to the amount that the same company would pay in State and County taxes if it were located outside of the reservation.

"Of course, no company will spend the money that is necessary in order to develop a large property upon a mere permit from the Secretary of the Interior which may be revoked at any time. The law, therefore, should specifically set forth what is required, and when the conditions are complied with, there should be no doubt about the right of the company to continue its operations within the reservation.

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"CARL HAYDEN."

UNITED STATES SENATE,
December 22, 1913.

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"I have an idea, without looking more closely into the matter, that reservations created by Executive Order, as distinguished from reservations created by Act of Congress, do not carry title to mining lands within such reservations. The law says that the mineral lands shall be free to exploration and purchase by citizens of the United States, and I have a doubt as to the President's power to modify that law by spreading Indian reservations over these lands. I shall bring this matter up in Congress soon after the recess. In fact, I have already introduced a resolution in the Senate inquiring into this very question, and the resolution now lies on the table to be taken up by me. After submitting such remarks as I shall deem pertinent, it will be referred to the Committee on the Judiciary for an answer to that question.

"M. A. SMITH."

UNITED STATES SENATE,
WASHINGTON, D. C.,
December 29, 1913.

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"I have read Mr. Anderson's letter with much interest. He correctly states that under the present law no rights can be acquired to a mining claim within an Indian reservation, and he is of opinion that it is fully within the authority of Congress to pass a law giving such rights to mineral locators as Congress may deem expedient. I feel very certain that many, if not most, of the members of both houses of Congress from the Western States, who have had personal experience, are opposed to the policy of locking up all the mining lands, and they take the position that it would be a wholesome thing if Congress should pass a bill providing for the working of mineral claims on Indian reservations.

"HENRY F. ASHURST."

Mining-Law Revision: How to Obtain It

BY EDMUND B. KIRBY, ST. LOUIS, MO.

(New York Meeting, February, 1914)

THIS meeting marks the point at which the long-standing dissatisfaction with the mineral-land laws, the innumerable protests against them, and the many isolated efforts to obtain relief, have developed into a general movement for their revision.

That part of the mining industry which is affected by these laws has three general organizations which are able to speak for it: the American Institute of Mining Engineers, the Mining and Metallurgical Society of America, and the American Mining Congress; all of which are represented in this meeting.

In the series of able and thoughtful papers presented here, prominent men have discussed the evils of the present laws and some of the reforms which should be made in them. We all appreciate fully the ultimate value of these studies; but we are also painfully aware of the fact that discussion of this kind has been going on for a quarter of a century without any other effect than a steady increase in the mass of printed records stored on library shelves.

In order to get any practical result we must induce an indifferent government at Washington to act, and to do this we must unite in pushing some practical plan whereby it may act in a simple and effective way and with the least possible amount of criticism or opposition.

The actual question before us is not whether the mining laws are bad; for their evils and absurdities are not only beyond discussion but also beyond the resources of a temperate and dignified vocabulary. It is not what particular changes ought to be made; for it is premature to make specific recommendations until there is some one to listen to them. Moreover, we all know that there are wisdom and experience enough available, and awaiting that time, for the creation of a code which would be a model to the mining world.

The practical question now is, how to obtain the revision; and since the American Mining Congress has of late restricted its attention to this phase of the problem I wish as one of its representatives here to present its views upon the matter.

The American Mining Congress is engaged in the work of inducing Congress to undertake a general revision of the mineral-land laws and to this end it is urging the appointment of a commission whose members shall be selected for their recognized knowledge and experience in the mining industry. This commission shall consider the mining laws of this and other countries and shall hold public hearings in the principal mining communities of the West and Alaska; giving full opportunity for the expression of public opinion concerning the problems before it. Its recommendations shall be presented to Congress in the form of a fully drafted mining code. It is not proposed to have this include deposits of coal, oil, phosphates, or salines, because these are generally regarded as the subjects of other and special legislation.

The American Mining Congress is therefore not attempting at present to formulate and recommend specific changes in the mining laws. It is concentrating its efforts upon the creation of machinery which will do this detailed work of the revision and will do it in a way calculated to inspire the confidence of the mining communities and appeal to the common sense of all men.

The definite plan of action thus proposed is based upon the conviction that no tinkering or patchwork revision can afford any perceptible relief. The present mining laws as a whole are hopelessly at variance with the geological realities of ore-deposit structure and also with the practical operations of prospecting and mining. Moreover, their various parts are so interdependent that it is practically impossible to correct individual faults without revising the laws as a whole.

The fact is also recognized that the problems involved are very technical and difficult, and that mining men are in much fear of changes framed by legislators who do not know these technical peculiarities or the practical effects of mining laws upon the industry. This apprehension has led to the prolonged endurance of present evils until these have become disastrous to the industry. It is therefore necessary for safety and for the quieting of this fear that Congress, in making the revision, should assemble and utilize the best wisdom and experience to be found among mining men. This is, moreover, the only course which will enable it to make a revision which will be satisfactory.

It is believed that no revision can be carried through which does not gain for itself the acceptance and support of the mining communities affected by it, and a working plan, to be effective, must provide a practical way of securing this acceptance. They are already in accord as to the evils of the present laws and the fact that a revision is necessary. With respect to the details of the changes required, however, there are natural differences of opinion, and it is necessary to compose such differences by bringing them all to a focus before some authoritative body which has the power of decision. This body or commission must necessarily have a

personnel which will be known to the mining communities and inspire their confidence.

It is also believed that the commission will find the most important part of its work to be the conduct, through its public hearings and otherwise, of such a campaign of publicity and discussion as will carry the mining public with it to the same conclusions. This would be accomplished by giving the public, in one way or another, full opportunity to talk itself out upon the questions at issue.

The suggested draft for a joint resolution of the Senate and House, which is given herewith, embodies the essentials of the plan proposed, which are as follows:

1. That the revision shall be general.
2. That the membership of the commission shall be restricted to men whose qualifications for the work are known to the mining industry.
3. That the commission shall hold its public hearings within reach of the mining communities and give the public full opportunity to express its views.
4. That the commission shall have some reasonable time limit set upon its task.

These four essentials require enough expansion to be self-explanatory, but prudence dictates that the temptation to add details should be resisted. Practical experience has shown that every detail introduced into a measure of this kind tends to create differences of opinion and to develop opposition, and the draft which will meet with the most favor is that which best presents the bare essentials, unencumbered by any details.

The work already done by the American Mining Congress has made it clear that the procedure described appeals to the judgment of the great majority of men and reduces to a minimum the number of objectors. In fact, it is believed to be the only practicable plan for obtaining the end desired.

Preliminary Draft Suggested for a Joint Resolution of the Senate and House

That Congress shall undertake a general revision of the laws relating to mineral-bearing lands and mineral rights within the United States and Alaska, and such revision shall cover mineral deposits of every kind except those of coal, oil, phosphates, and salines, which are set aside as the subjects of other and special legislation.

In view of the technical nature of the problems presented by the work it is desired to secure first the results of the knowledge and experience which exist among those who are engaged in the mining industry.

To this end the President shall, within 60 days hereafter, appoint a

commission of five members, who shall be selected for their recognized knowledge and experience in the mining industry.

The commission shall consider the mining laws of this and other countries and shall hold public hearings in the principal mining centers of the Western States and Alaska, giving full opportunity for the expression of public opinion concerning the problems before it. Its recommendations shall be presented in the form of a fully drafted mining code.

Within six months after the appointment of the commission its report shall be delivered to the President, who shall within 30 days thereafter transmit it to Congress with his further recommendations, if there be any.

Members of the commission shall receive $—— per diem, with expenses, and shall engage such clerical assistance as may be necessary for the work.

Clause providing for the necessary appropriation.

Discussion

J. B. Tyrell, Toronto, Canada.—It is rather an onerous duty I am asked to perform here in telling you how our attempt was made to draft a new mining code for the Dominion of Canada. The Dominion of Canada does not own all its wild land. Most of the various Provinces, like many of your States, own their public lands, so that the Dominion only owns a certain proportion of the more distant vacant land. These lands are covered by the Dominion mining law.

A few years ago the Canadian Mining Institute suggested to the Dominion government that it might be allowed to co-operate with the government in the drafting of a new mining law for the Dominion, in the hope that such a mining law might not only be useful to the Dominion of Canada itself, but might also serve as a model for the various Provinces of Canada, and that sooner or later the Provinces would pass laws which would closely approximate this model law which we were to draw up.

The Dominion government threw the responsibility back on the Canadian Mining Institute and said to it: "You draw up the Act, and if possible we will pass it for you." That was under a government which two years ago went out of power, and since the new government has come into power, while it has considered our draft sympathetically, it has not passed it into law.

We hope it will take that draft into consideration during this year and enact it into law, because it embodies, as closely as we can determine, the kind of law which we think would be best for Canada.

Now, the constitution of the committee that was appointed to draft this law was about as follows: We chose three or four of those actual mining members of the Canadian Mining Institute whom we thought had most experience and were most competent to express opinions on what a min-

ing law should be. We also added a couple of lawyers to the committee, who were to furnish the legal assistance in doing the work and in putting the drafts into proper legal form. It was not their duty, nor did they assume, to dictate what that law should be, but they were to assist us in framing the law; so that it would be a law which would be considered as being properly drawn by the courts.

I am not going to give you any synopsis of that draft. It is still a draft, though we hope to have it enacted into law this year. Whether it will be or not, I do not know. But what I have said may give you some idea of the way in which we undertook the preparation of it. We have endeavored to draw up a mining law for the Dominion of Canada, covering the Federal lands, which we hope will serve as a model, and be copied by the Provinces as soon as possible, so that we will have fairly harmonious mining laws throughout the entire Dominion.

In Canada, we do not sympathize with the apex law, which as I understand it, if I understand it aright, was a product of an erroneous interpretation of Cordilleran geology. Leaving out the ore-bodies in the Rocky mountains and considering only those occurring in the Pre-Cambrian and other great formations throughout the eastern portion of the country, I do not think that the apex law would have suggested itself to anybody.

Horace V. Winchell, Minneapolis, Minn.—I wish to call attention to Senate File No. 4373. Feb. 5, 1914, Mr. Smoot introduced the following bill [not included in this report], which was read twice and referred to Committee. Now, in connection with the bill, I would say that it has been suggested that this Commission shall consist of three members, all of whom shall be lawyers, experienced in the practice of mining law. And there is a provision regarding a third party, constituting a member of the Geological Survey, that is eliminated. And the provision that said code shall not deal with coal and other minerals has been crossed out. The Commission *may* hold hearings, instead of being compelled to, as in the original law. Will Senator Walsh advise us as to the interpretation of this amendment, and others which he may have in mind at this time?

Senator Thomas J. Walsh, Helena, Mont.—The exactions incident to my official duties have been so continuous in character as to deny to me any opportunity for reflection concerning any subject that might be of special interest to this assemblage and in respect to the discussion of which my views ripened by study could be regarded as a contribution. I shall, in this situation, content myself with presenting a brief review of legislation now pending in Congress, which from its nature will evoke the attention of the members of the American Institute of Mining Engineers and the men with whom they come into contact professionally.

The Committe on Mines and Mining of either House of Congress has not heretofore been regarded as much more than one of the numerous paper

committees, created and preserved chiefly to afford to the Representative designated as its Chairman, a needed clerk. It bids fair at present, however, more because of the important legislation affecting the mining industry that crowds upon the attention of Congress than by reason of the personnel of its membership, to be transformed from a more or less moribund organization to an active legislative force. The haste in which this *résumé* is necessarily prepared impels me to confine my remarks to measures that have been referred or which it is expected will be referred to the Senate Committee.

The Revision Commission Bill.—It has had under consideration a bill introduced by Senator Smoot, for the creation of a Commission, charged with the duty of revising and codifying the laws in relation to the appropriation and occupation of mineral lands of all kinds, a subject which, as I am advised, has had repeated consideration by this body. As the bill came to the Committee the Commission was to consist of three members, one of whom should be a lawyer of experience in the practice of mining law; one a mining operator, and one an officer of the Geological Survey. Being referred to the Department for an expression of its views, it was proposed that the membership be increased to five, giving the Bureau of Mines a representative and an additional representative to the operators. It was, however, urged before the Committee that as the work devolving on the Commission is the preparation of a draft of a code of laws, that in the past have given rise to interminable litigation and that are likely to be a fruitful source of perplexity to the courts for years to come, it ought to be entrusted exclusively to lawyers of eminence and character, conversant with the troubles that have been encountered in the past, and most competent from this experience and learning to devise a system under which unnecessary controversies may be avoided in the future. While the suggestion might appear to have originated in a desire upon the part of the members to take care of their brothers of the law, a little reflection will exhibit much merit in it. It was advanced that the Commission being authorized to hold public hearings throughout the mining regions affected, and elsewhere, at will, it would unquestionably invite an expression of views from operators, engineers and prospectors, from representatives of the Geological Survey and the Bureau of Mines. The bill contemplates that a report shall be made before Jan. 1, 1915, and provides that each member of the Commission shall be paid a salary of $500 per month for the time actually devoted to the work. It is now over 40 years since our system of laws in relation to the disposition of mining lands was devised. Generally speaking, it has met the conditions in a most satisfactory way, excepting always the part dealing with the disposition of lands containing coal. That part of the law never would have been operative at all had not the practice now condemned as criminal been pursued. As the appropriation of coal lands has all but

ceased in consequence of the failure of the law to recognize that an entry of 320 acres will not justify the expenditure necessary to the mining of coal on a commercial basis, a revision in respect to lands valuable for coal is imperative. Aside from that feature, however, the conviction is quite general that the extra-lateral right gives rise to complications so numerous and serious, it is such a prolific breeder of litigation, not infrequently characterized by imposition and perjury, that it ought to be abandoned. The idea in which it had its origin—a just purpose to stimulate the prospector by assuring to him the vein discovered through his sagacity and his self-denial—was most commendable. But in practice it often served to deprive the enterprising miner of the legitimate fruit of his toil and his expenditures. Every lawyer of experience is familiar with instances in which ore bodies of great value have been uncovered by expensive development made by the owners of the claims in which they are found, and who have been obliged to yield them up upon the claim of an apex in adjacent territories, the owners of which had no suspicion of their existence and who never exhibited enterprise enough to find them.

It will be found profitable to compare the working of the system to which we have become attached, with those that have been developed during the past two score years in the English colonies, the Latin-American republics and other nations that have been required to legislate concerning the public mineral lands. An enlightened public sentiment concerning our mineral-land policies can be formed only in the light that is afforded by knowledge of the kindred systems of the progressive peoples of the earth. A compilation of such laws, accompanied by a brief explanation of their character and the measure of success which has attended their working, is all but essential to comprehend the active value of our own, to make appreciable such defects as have not obtruded themselves upon our notice, and to perfect our system in the respects in which it appears faulty. However competent any one or more members of Congress might be to undertake or perform such a task, it is simply impossible, except they neglect duties no less imperative, to devote to the work the time necessary to accomplish it. In all probability the Committee will report this bill favorably.

The Alaska Coal Land Bill.—Some of the questions with which the Commission will be called upon to deal, should one be appointed, brook no delay. They must be met at once and solved in some way looking to revision later in the light of facts brought out or views advanced by those deputed to study the subjects as a whole. Of this character is the question of how to open the Alaska coal deposits. The bill providing for the construction by the government of railroads in that Territory from the seaboard to the inland waterways has passed the Senate and will speedily, it is believed, be approved by the House. President Wilson's

sanction of the general purpose of the Act has been given in advance in his message to Congress. It must be accompanied by an Act which will permit and invite the working of the coal fields. It is idle to imagine that the Executive Department will advance one step toward the construction of railroads in Alaska unless assured in advance that the coal mines will be producing to afford fuel for construction purposes and tonnage when the road is built. The Senate Committee has under consideration a bill which is the result of repeated conferences participated in by the Secretary of the Interior and his staff and the Chairmen of the House and the Senate Committees respectively on Public Lands, Territories, and Mines. It is a frank adoption of the leasing system, to which none of those having any conspicuous part in the preparation of the bill confess any attachment. The Congressional members are all convinced, however, that the concession is essential to the necessities of the case. They entertain the view that to enact a law providing in any terms for the disposition in fee of coal lands in Alaska would be in effect to doom the country to another decade of inaction. I am myself of the opinion that any Secretary of the Interior who should permit Alaska coal lands to be patented under any kind of a law passing the fee would be driven from public life, and it would be good fortune if he did not pull down the temple of the administration of which he formed a part as he passed out of it. It is to be regretted that a great public question such as this is cannot be debated dispassionately and without impugning the motives of those who adhere to what may be said to be the Western view, except when and in so far as the conditions point to selfishness in those upholding it. The promoters of the leasing plan never admit the possibility of an honest difference of opinion concerning the wisdom of the departure they propose. All who oppose them are involved invariably in the common denunciation which is leveled at the plunderers of the public domain and the defenders and apologists for such. There has been no deliberate judgment by the American people on this supremely important question. They have been turned by invective from the consideration of it. The leasing system was tried in connection with the lead lands of the Mississippi valley, and abandoned after proving a dismal failure. Probably the essential differences in the conditions under which it was tried and those now prevailing deprive the experience we had under it of anything like controlling force, but if so the public has not been advised as to why the same troubles are not in store for us. Calumniation has been so long the portion of those who have sought to gain a fair hearing for the system of alienation in fee that few remain who have not despaired of securing considerate attention to the merits of that plan. Anyway, the friends of Alaska are without hope of convincing the public mind, at least not speedily, that as to coal deposits, popularly believed, and doubtless with justice, to be exceptionally rich, the leasing system is not a most doubtful

experiment. The people of Alaska pray for any kind of a law which will permit them to mine coal. They have ceased to debate the merits of rival systems. It must be confessed that the plan of reserving title in the government is growing in favor. The Western Representatives are much more tolerant of this idea than they once were. The legislation of such States as Colorado and Montana concerning their own coal lands, forbidding their sale but authorizing the operation of them under leases, is appealed to with embarrassing effect. It is true that the policy of the State is primarily to make as much money as it can out of its school lands, while the policy of the Federal government is, or ought to be, to make its lands serviceable in the development of the sections in which they are situated. But the State is not altogether unmindful of its larger interests in the sale of its granted lands, and the policy of local development is as well subserved under a leasing system, if all the avails are devoted to improvements within the State, instead of going to meet the general demands upon the Federal treasury. The Northern Pacific Railway Co. has the most vital concern in the rapid development of the territory adjacent and tributary to its lines. But it has also adopted the leasing system as to its coal lands and declines to sell such at any price.

Those responsible for the Alaska coal-land bill referred to find sufficient justification in the foregoing to tender a measure recognizing the leasing system. Under it the Secretary of the Interior is authorized to withdraw eight sections in the Bering River coal field and twelve sections in the Matanuska field for the use of the navy, or to be used in connection with government construction work, or for disposition by Congress in case of oppressive conditions arising from monopoly, it being contemplated that the government might in the future deem it the best solution of difficulties which might arise similar to those encountered in connection with the anthracite coal situation in the East, itself to supply the market from its own fields. Leases are authorized for indeterminate periods, with provisions for readjustment of prices every 20 years, no lease to be for more than 2,560 acres to any person or corporation. Drastic provisions are inserted in the law to prevent evasion of the provision limiting the area in which any individual may be interested. Forfeiture and imprisonment are the result of conviction. It is believed the risks are so great that few will care to take the chances involved in an effort at monopoly. The royalty is fixed by the lease, but cannot be less than 2c. per ton, and it all goes toward the redemption of the bonds issued for the construction of railroads in the territory and for purposes of a similar character when the obligation created by them is discharged. The lessee is entitled to sue the government on any cause of action arising out of his lease in the courts of Alaska—so that any arbitrary or destructive policy on the part of the Department may be restrained, and questions arising upon the construction of the lease may be determined as they would

be between private parties under like circumstances. To compel the operation of any ground leased, a rental in addition to the royalty is exacted at the rate of 25c. per acre the first year, 50c. an acre annually for the next four years, and $1 an acre for each year thereafter. For local use the Secretary is authorized to issue permits without any charge for the working of tracts not to exceed 10 acres, the purpose being to permit the homesteader and miner to secure coal for his own use at an adjacent bed.

The Radium Bill.—A third bill before the Committee which has given rise to much discussion appertains to lands containing radium-bearing ores. These are mainly pitchblende and carnotite. The former is often, perhaps usually, found in metal-bearing veins and in association with the precious metals as well as with zinc and lead; the latter, so far as known, appears only in veins or pockets in sedimenatry rocks. The carnotite ores are the chief source of supply. They abound in an area reaching from Colorado into Utah, 150 miles long and varying in width from 5 to 25 miles. Discoveries have been reported in Arizona, Montana, Idaho, and South Dakota, but no authentic information is available of any workable fields save those of Utah and Colorado. The wonderful advance made in the use of this remarkable agency in the eradication and cure of cancer and other malignant growths has directed the attention of the world to the sources of its supply. The exceptional riches of our Western fields have made the output of them eagerly sought after by the laboratories and reduction works of Europe. Two great plants located in the State of Pennsylvania are now treating the ores and claim to be supplying the trade each with a gram a month, salable at about $120,000. Thus far their production has gone very largely to foreign markets, as has practically all the ore not treated by them. They own the claims from which their supply is drawn—one of the companies having acquired about 140 claims. Another association has 80 odd; a third, 40 or more. Though the crude ore which is the source of by far the greater part of the products of the works in Europe comes from this country, our surgeons are forced to go there to procure their supply. Unmistakable evidence is at hand of something like a race to purchase or locate every deposit of any prominence—and surgeons of eminence who are intensely interested in the success that has been achieved in the use in therapeutics of this singular substance, and the still more marvelous possibilities that experimentations are constantly revealing, became genuinely alarmed on visiting the region from which the ore comes lest the whole of it should speedily fall into the hands of a monopoly which might maintain the price of its product so high as to make it available for the treatment of those only who could afford to pay anything that might be demanded. Before the American ores entered the European market the chief source of supply for the Continent was the pitchblende ores of Joachimsthal,

but the Austrian government prohibited the exportation of any ores containing radium—preferring to preserve the supply of the Empire for domestic use. The German Emperor is making extraordinary exertion to procure an adequate supply for the hospitals in his country.

These conditions prompted the introduction of a bill which obligates the locators of all claims containing radium-bearing ores to sell their products to the United States at the market price to be fixed by the Secretary of the Interior. Development work or mining during a period or for periods aggregating four months are required, and even after patent, if the property is not worked with diligence, the Secretary is authorized to enter upon the property and mine it, paying to the owner market value of the ore less the cost of extraction. Rights to claims located prior to the passage of the Act are, of course, not affected, but the government is given the preference right to buy the output of all claims hereafter located. The Bureau of Mines is perfecting a process which it is claimed will enable it to reduce the ores at a cost not to exceed that now attending similar work by private companies.

Two questions are of first importance in the consideration of this measure—first, whether it is justifiable to impound all ores produced in our territory to supply the needs of our people; and, second, whether the peril of monopoly is sufficiently imminent to justify the government in itself undertaking the work of extraction.

Oil and Gas Bill.—Various other bills related in character to those referred to will be considered in conference, such as has been mentioned, and then introduced. First in importance is an oil and gas bill. The basic feature in this bill is one which permits the discoverer to purchase a limited portion of a tract for the exploration of which an exclusive license is issued to him, the remainder then being leased. It is proposed to give the adventurer the exclusive right for two years to prospect over four sections, if they are distant 100 miles from a producing well, and over one section if it is less. Should he discover oil or gas, he is entitled to locate, in the one case 640 acres, in the other 160 acres, of the land included in his permit, acquiring title under the procedure prescribed in the case of placer mines.

Potassium and Sodium Compounds.—The same principle is to be made applicable to the disposition of valuable deposits of chlorides, sulphates, borates, or nitrates of potassium or sodium.

Phosphates.—Phosphate deposits it is proposed shall be leased by competitive bidding in tracts not to exceed 320 acres. The royalties from all leases of lands outside of Alaska, except so much as is deemed necessary to defray the cost of administering the laws (for this principle applies to all leasing measures), go into the reclamation fund.

Coal.—A general coal-land bill has been prepared by the Department on the same lines.

The Committees of both Houses, the Department, and the Congress will be thankful for any consideration you may give these various measures and for any helpful suggestions you may be moved to make concerning any of them.

Horace V. Winchell.—Now, gentlemen, you will see something is doing over in Washington—many things we do not know anything about, and which we should know about. If we are in the mining business, as some of us suppose we are, these laws are of vital import to our business, as well as to the welfare of the country. The first thing of interest, it seems to me, is in connection with this Commission, under the resolution introduced, and I would like to know if there are any resolutions to be introduced here for our consideration at this time.

E. B. Kirby.—The number of members suggested for this Commission by the American Mining Congress was five. It was not attempted to specify as to their character, except in private character the people who were considered the best; the idea was to have the President appoint a Commission of five, and then it was expected when it reached the President there would be an opportunity for mining men and members of our Institute, and the Congress, to present their own recommendations as to the character of members suitable for the Commission. There was a general fear that any attempt to dictate to the Congress or to the Senate would arouse opposition. The original idea was for a Commission of five.

George A. Packard, Boston, Mass.—It seems to me it would be a mistake to allow this bill or the suggestion as to this Commission to be read before this meeting, and have nothing said in regard to the suggestion that the bill be amended, and that the Commission should consist of three lawyers.

I think there should be some expression at least to the effect that the mining communities should be recognized. It seems to me the Canadian scheme was a most delightful one. I do not know how they managed to have four mining men and two lawyers, when the two lawyers were only expected to advise as to the legal method of preparing things. We have lawyers in this country who would be glad to go as members of this Commission, but I do not think we want it to be considered that it is the sense of this meeting that we would like to be represented entirely by lawyers. I think the majority should be mining operators, mining engineers or mining men.

Denis M. Riordan, New York, N. Y.—My predilections would be in favor of a Commission of five, and I would be in favor of one-fifth of the Commission to be a lawyer. I think the three mining societies and a representative of the government representing the Bureau of Mines, and the Geological Survey, would make a well-balanced and well-composed Commission. But I think the time has come when such a Commission

is indicated, and I am in full accord with anything that will restore the ambition of the man who has done so much to make the country west of the Missouri what it is to-day, namely, the prospector.

HENNEN JENNINGS, Washington, D. C.—I think the mining man will immediately admit that the lawyer is more competent to draft a bill than himself. But as to the substance of the bill, it seems to me that the locators, owners, engineers, the operators, should know better what is wanted than the lawyer. Therefore in a Commission of that kind, I should say that a larger committee would be better than a small one, it being of course understood that the legal representative should draft the bill after the substance had been arrived at by questioning of witnesses by those who best should know the work, and after a conference and full discussion of capable and honest representatives of various sides of the question. I think this would meet with more general satisfaction and stand better the future test of time.

It is a vast subject for three men with no practical experience, no matter how able they may be, to grasp everything connected with the subject and law.

SENATOR WALSH.—I feel it to be my duty to advise this gathering that I am not at all responsible for the suggestion of the amendment in regard to the character of the membership of the Commission, although I am free to admit that the merit of the proposition appealed to me very strongly. It was suggested to me by a member of the Committee, of well-known ability and wide experience, and he told us why he suggested it. He said he was appointed a member of a Commission in his State for the purpose of revising their laws with reference to mining. He was made a member of the Commission with two other gentlemen, who were not lawyers. He saw or thought he saw, from a lawyer's standpoint, some very serious obstacles to the working of the plan they proposed. He said in fact that he was confident—and the result showed the soundness of his judgment—confident of his position, but his views were overruled by the other two members of the body. The reason for that is that men not engaged in the profession of the law could readily suggest a line of action which it would be impossible to put into force, because, possibly, of constitutional objections. And the lay member would not always appreciate the force and applicability of decisions which had been rendered by the courts, and which would be controlling on the interpretation of the proposed statute's provisions. And it was suggested that it would be construed in a way to defeat the very purpose for which it was drafted.

Now, it is really a work of drafting, and inasmuch as the Commission will have available for its services the views and opinions of all those who are interested, it would seem not to be necessary at all that any of us

should be represented on the Commission. But you will bear in mind about that, with respect to that matter, you gentlemen represent only one particular branch of the mining business. The prospector, who is perhaps greatest in number, in the revision work would have no representation upon the Commission at all, in all probability. And you are likewise to bear in mind that he does not always look on you gentlemen as having interests absolutely identical with his own. And so there is a political aspect to this thing which must be borne in mind. I must say I haven't any very fixed conviction at this time with respect to the wisdom of the change proposed, but I rather feel that perhaps some gentlemen feel it was a rather invidious amendment directed at them. I do not think that is the case at all.

HENNEN JENNINGS.—In case the Commission had conflicting views, who would decide? You have to take testimony, and you must adjudicate as to its worth. Now, if you do not have interested people on the Commission, how are you going to arrive at a judgment that will be universally satisfactory?

SENATOR WALSH.—The decision would be arrived at in the same way, whatever the composition of the Commission, as the report, if it is reported, will be a majority report; the only trouble is that with three lawyers, there would be three separate reports.

Uniform Mining Legislation in All the States Based on Federal Act

BY C. L. COLBURN, DENVER, COLO.

(New York Meeting, February, 1914)

THE statutory requirements of the States and the district rules are, broadly speaking, similar. There is just enough difference to make it tantalizing.

DIFFERENCES IN STATE LEGISLATION GOVERNING THE LOCATION OF MINING CLAIMS

Discovery

Discovery is the first step in the location of the claim. The provision of the Revised Statutes (2320) is, "No location of a mining claim shall be made until the discovery of the vein or lode within the limits of the claim located." Strictly speaking, discovery may be defined as the finding of ore or metalliferous rock in place in a well-defined vein. This definition was too strict, so discovery extended later to cover such indications of the presence of ore, within rock in place, as would justify an experienced miner in spending his time and money with a reasonable expectation of finding ore in paying quantities. According to Colorado statutes a discovery must show a well-defined crevice; in Arizona, a lode, deposit, or mineral in place; in Montana, a well-defined crevice or valuable deposit; in Nevada, a lode or deposit of mineral in place.

It is wrong to require a discovery. An honest prospector, wishing to obey the law, finds himself compelled, in most cases, to evade this point. In Clear Creek district, Colorado, a quartz seam will constitute a discovery; in Butte, a red capping; in Leadville or Ely, it is any place where a man can find a piece of vacant ground big enough upon which to sink a 10-ft. hole. If the vein or deposit outcrops a man can show a discovery, but if it does not outcrop it is foolish to compel him to show one; and this point has been gently side-stepped. Any hole 10 ft. deep now constitutes a discovery. It is no use having laws that the people cannot consistently obey. No sane man will dig unless he expects to find mineral, and he should be protected while digging. He should be required to show that he has mineral ground only when he comes to patent.

Time to Sink Discovery Shaft and Complete Location

When a discovery has been made, the discoverer is entitled to retain undisputed possession of his claim for a reasonable time in order to complete the acts of location required by law. The length of time for this purpose is not fixed by the law of the United States, but is left to the law of the State or the regulations of the district. In Colorado, Idaho, Montana, North Dakota, South Dakota, Oregon, and Wyoming, he has 60 days to sink a 10-ft. discovery shaft and to complete his location. In Arizona, Nevada, New Mexico, and Washington, the time is 90 days. In Alaska, a discovery shaft is not required; in California and Utah, the matter is left to district rule. Most of the States allow the lode to be exposed in an open cut, cross-cut, or tunnel instead of the 10-ft. hole. Some States specify the amount of excavation work necessary to show the discovery.

Marking the Location of the Ground

The provision of the Revised Statutes (2324) is as follows: "The location must be distinctly marked on the ground, so that its boundaries can be readily traced." The law of the United States does not define what kind of marks shall be made, or where they shall be placed. In Colorado, the surface boundaries must be marked by six posts, one at each corner and one at the center of each side line, hewed or marked on the side toward the claim. In New Mexico, four substantial posts or monuments, set one at each corner of the claim, are all that is necessary. North Dakota requires two posts, one at the center of each end line, in addition to the six posts required in Colorado. Arizona requires six posts set 4 ft. above ground or stone monuments 3 ft. high. Montana requires posts 4 in. square by 4 ft. 6 in. long, 1 ft. in the ground, and a mound of earth or stone, 4 ft. in diameter and 2 ft. high, placed around each post. If a stone, not a rock in place, is used, it must be 6 in. square by 18 in. long, set two-thirds its length in the ground. In Oregon the posts need only stand 3 ft. above ground or there may be mounds of stone 2 ft. high. In Utah the details of marking are left to district rules.

Posting of Notice of Location

The rules and regulations of the several mining districts or States generally require the locator to post upon his claim a notice of his location. What this notice must contain is governed by the particular statute or regulation applicable in the district where it is made. Generally it contains the date, extent of claim, name of the claim, and name of the locator.

Record of Location Certificate

The final step in the location of a claim is the filing of the location certificate. This is not required by the U. S. law, and therefore is left to the States and districts. In Arizona, Idaho, Utah, Oregon, and New Mexico the statutes require the making of location certificates in duplicate, one to be placed on the claim and one filed for record. In the other States this is not required. In Montana and Idaho the location certificate must be sworn to before it will be admitted to record.

In the majority of cases the location certificate must be filed with the County Clerk and Recorder of the county in which the claim is located. In North and South Dakota the certificate is filed with the Register of Deeds; in Washington with the County Auditor. In some States the certificate may be filed with either the County Clerk and Recorder or with the Mining District Recorder; in other States the claimant must file with both the County and the District Recorder. Alaska is divided into three Recording Divisions which are subdivided into Recording Districts. Location certificates are filed with the Recorders of these districts.

Size of Claim

The maximum length of a lode claim is fixed by Congress at 1,500 ft. The width may vary from 50 to 600 ft., according to State or district regulation. North and South Dakota fix the width of a claim at 300 ft., but allow the counties to increase or decrease it within the Congressional limit. The width of claims in Colorado was formerly 300 ft. and in some counties 150 ft. Recently the legislature amended the laws, increasing the width to 600 and 300 ft., respectively, thus doubling the size in all sections of the State. In all the other States the width is 600 ft., so that a claim equals a little more than 20 acres. The tendency seems to be in favor of the larger claims.

Suggestions Leading to Uniformity

Congress can make uniform laws concerning the appropriation of mining claims. This can be done by leaving nothing whatever for the States to do. A man wishes to take up a homestead. He does so under the Federal law and Land Office regulations. The States have nothing to do with the matter until the man "proves up" and receives patent to his land. It would be a bad mix-up if the States could regulate the size and shape of these homesteads, the amount of soil that the homesteader should till each year, and countless minor matters. The miner should be put in the same position as the homesteader. He should make his application directly to the government and should be relieved of State interference.

The Federal law of 1872 and the State statutes were all based on the theory that valuable minerals were found either in steeply dipping veins or in placers. The prospector in those days was looking for just such deposits. To-day mining conditions have changed. The old prospector has gone. Modern metallurgical practice has made it possible to treat low-grade ore at a profit. Mines are now sought and found not only in steeply inclined veins, but also in large irregular masses and in flat-lying deposits. This, then, is surely an opportune time for Congress to revise our mining laws.

The following suggestions will show how the mining laws can not only be made uniform, but simplified:

1. Mining claims should be taken up according to legal subdivision. Forty acres should constitute a claim.

2. Upon proper application the claim should be withdrawn from the public domain and held for the use of the claimant, just as farming land is withdrawn and held for the homesteader. No conflicting claim of any kind should be granted as long as the claimant obeys the law.

3. The claimant should be required to perform 1,000 cu. ft. of development work each year. Proof of this work must be filed before Feb. 1, for the previous year.

4. The claimant should be allowed to apply for patent after excavating 5,000 cu. ft. of material. He should at that time show that he has mineral ground.

5. The claimant should be compelled to apply for patent within five years.

6. After a patent is issued the claimant should be entitled to the surface and all mineral lying under it, and between planes passing through the center of the earth and the boundaries of the surface.

7. Failure to comply with any of the above requirements should constitute a forfeiture of the claim, and the land should be thrown open for other claimants.

8. One claimant should not have more than eight claims under application at any one time.

Laws based on the above suggestions would serve equally well for all kinds of mineral deposits and for all kinds of minerals.

In the case of oil and natural gas a claimant should be required to sink 400 ft. of well each year, and he should also be debarred from sinking a well within a fixed minimum distance from his boundaries.

Character of Title That Should be Granted by Government

BY GEORGE W. RITER, SALT LAKE CITY, UTAH

(New York Meeting, February, 1914)

Our mineral-land laws need revising so as to provide definite title at the outset to the mineral deposits within any definite piece of land. The laws as they now stand, especially those applicable to lodes, breed uncertainty as to rights of possession prior to patent; and to my mind this is the worst feature of all, worse even than the apex bugbear.

It is now almost impossible for anybody to tell with certainty what mineral rights exist within any area that is not covered by patent, or whether any valid rights exist at all. Our system is unique in permitting individuals to appropriate and exploit mineral lands of the public domain without notice of any kind to the Federal government, and to relinquish them without any ceremony at all. The result is a clouded record that cannot be cleared up until each claimant is put to some sort of final proof. In order to accomplish this, new Federal legislation will be required. The requirements for a mineral survey and the proceedings for patent have always been cumbersome and expensive; and perhaps out of regard for the poor claim owner, who can ill afford the outlay for that sort of thing, the law does not require him to go through it unless he chooses to do so. Consequently, every active mining district has become encumbered with tangled groups of doubtful or conflicting locations, whose rights and boundaries, when any valuable ore is found, must usually be determined by lawsuits that are as expensive and as distressing as the stakes are high. So deeply has litigation entered into our mining system that a claim whose rights have never been disputed would probably be set down offhand, by a miner of the old school, as of no value. Think of the litigation over rights of possession on the Comstock lode—12 leading companies involved in an aggregate of 245 suits within a period of less than eight years!

Ambiguous local records; the chance of erroneously placed or obliterated monuments; doubt as to the sufficient performance of the statutory annual labor; uncertainty as to prior conflicting or overlapping locations; anxiety as to the changing attitude of the Department of the Interior and the Forest Service—such considerations as these make an unpatented mining claim an unclean thing in the eyes of possible investors. Is it any wonder that they keep themselves and their money at a safe distance,

and that prospecting for new ore deposits has become decadent for want of the funds necessary to carry mining ventures through the period of infancy?

The uncertainty as to rights of possession is not restricted to lode claims, but extends to placers, including lands appropriated for petroleum. The Department of the Interior has itself been guilty of much floundering in efforts to apply the law to lands of this latter class. The speculative spirit is easily aroused by signs of the existence of oil within a new district, and, since there is no such thing even as a preferential right within a legal subdivision of land until oil has actually been developed, rival speculators may often be found drilling wells alongside of one another in headlong haste to gain the first right to make a legal appropriation. This practice is not only wasteful, but it tends toward monopoly, since a race of this kind is necessarily to the swift and strong.

There seems to be no good reason why the present requirement as to discovery before location should not be done away with frankly, or why all mineral lands, including those containing lodes, should not be located and entered in units conforming to the public-land surveys, without requiring further survey or plat. The law already provides that for purposes of a placer claim a legal subdivision may be further subdivided into 10-acre tracts, so that a claim may be made up of strings or groups of 10-acre units, no further survey or plat being necessary.

There seems to be no good reason why the lands already appropriated for mining purposes should not be officially surveyed without delay, and the claimants required to proceed to patent.

There seems to be no good reason why the public-land surveys should not be extended at once over all mineral lands of the public domain, or why the respective Federal land offices should not be made the places of record for all new mineral locations. If appropriators were given the option of having an official survey made at the outset or of making the boundaries of a location conform to the public-land surveys, I believe that locations by legal subdivisions would soon become popular. There seems to be no good reason why such record in the Federal land office should not take the form of a mineral entry, so that the claimant might always know that he had at least preferential rights to the land, and so that other citizens could tell from consultation of the records exactly what lands were unappropriated.

Opinions may differ as to whether a mineral patent ought to be a final relinquishment of government ownership, as under our present system; or whether the title ought to revert to the government upon failure of the grantee to pay an area tax at stated intervals, as in Mexico; or whether some new system, such as leasing under government ownership and control, ought to prevail.

The Mexican system has several features to commend it. The filing

tax and the annual area tax are checks against the appropriation of mineral land by triflers. And while to the *bona fide* miner these taxes are more expensive than are the burdens imposed by our own laws, he generally prefers the Mexican system because his grant is practically incontestable except for non-payment of taxes, and is so definite from the very outset that he and his grantees always know and his neighbors can know exactly what the grant covers and what it does not.

I hardly think many of us ever expect to see our Federal government participating permanently in the development and operation of mines. Such a system would not only be contrary to our national traditions, but commercial success could hardly be expected in competition with private enterprise. No matter how conscientious and efficient the several department chiefs and their subordinates may be, their activities are limited so strictly by the terms of each appropriation bill that they are handicapped in comparison with private concerns. A simple instance may illustrate this point. The surveys of the public lands call for the preparation of several copies of each plat, and until recently these copies were all made by the laborious long-hand process. After it had been demonstrated to the Commissioner of the General Land Office that the duplication of these plats by some mechanical or photographic process would tend toward both economy and accuracy, he was unable to change the method at once because the appropriation bill permitted the employment of draftsmen but did not provide for the purchase of mechanical apparatus.

Our form of congressional government is also a valid argument against the leasing of mineral lands. What is there in the government's past treatment of the mineral-land question to inspire enthusiasm over a system of direct Federal control? The dilly-dallying over the surveying of the public domain; the willingness for more than 40 years to continue disposing of the mineral lands under makeshift laws; the floundering on the question of lands containing petroleum; the hit-and-miss classification of the lands given away as subsidies to new railroads, the vacillation and recrimination over the coal lands of Alaska—with these bits of history fresh in our minds, how many of us would care to gamble our possessions against the whims of ephemeral law makers and transitory office holders? Is it not enough to be obliged to gamble against the whims of nature?

Congress acts only slowly, and then only in matters upon which the people have shown deep feeling. I think myself that the reason why we have made so little headway in obtaining rational legislation on the details of our mineral-land law, is that the people have been satisfied with the basic principle of the existing law, which declares that the mineral lands of the public domain shall be free and open to occupancy and exploration by citizens or intended citizens, and that the mineral

deposits or the lands containing them will be sold by the government to all that have shown good faith in developing them. Real property with strings to the title has never been popular in this country. Our forefathers had seen enough of leaseholds, restricted estates, entails, and that sort of thing in the old world; and when the opportunity came to them to start a new order of things, they were quick to cut away from forms of title other than in fee simple. Perhaps it is the dread of chance return to an old-world system that "puzzles the will, and makes us rather bear those ills we have than fly to others that we know not of."

The Classification of Public Lands

BY GEORGE OTIS SMITH, WASHINGTON, D. C.

(New York Meeting, February, 1914)

THE Secretary of the Interior in his recent report to the President has defined the new public-land policy, which is in fact "but a new application of an old policy." His words may be more acceptable on this subject of land classification than the repetition of phrases which have served some of us for several years. Secretary Lane says of the past:

"Congress has always been most generous as to the disposition of the national lands. . . . There was land for all, and it was the government's glad function to distribute it and let those profit who could. . . . And this generous donor was not so petty as to discriminate between kinds of lands, the uses to which they could be put, or the purposes which those might have who got them. Land is land, save when it contains minerals; this was roughly the broad principle adopted. To classify was a task too difficult or not worth while. The lands would classify themselves when they arrived in individual ownership. And so the door was opened for monopoly and for fraud."

Of the reaction and the evolution of a new policy, the Secretary continues:

"A reaction was inevitable. If lands were to be withdrawn from public service, why might not the government do the withdrawing itself? The old philosophy that 'land is land' was evidently unfitted to a country where land is sometimes timber and sometimes coal; indeed, where land may mean water—water for tens of thousands of needy neighboring acres. For the lands of the West differ as men do, in character and condition and degree of usefulness. We had not recognized this fact when we said 'land is land.' Lands fitted for dry farming and lands that must forever lie unused without irrigation; lands that are worthless save for their timber; lands that are rich in grasses and lands that are poor in grasses; lands underlain with the non-precious minerals essential to industry or agriculture; lands that are invaluable for reservoir or dam sites—these varieties may be multiplied, and each new variety emphasizes the fact that each kind of land has its own future and affords its own opportunity for contributing to the nation's wealth.

"So there has slowly evolved in the public mind the conception of a new policy—that land should be used for that purpose to which it is best fitted, and it should be disposed of by the government with respect to that use. To this policy I believe the West is now reconciled. The West no longer urges a return to the hazards of the 'land is land' policy. But it does ask action. . . . It asks that the machinery be promptly established in the law by which the lands may be used."

Following Secretary Lane's thought, the public lands need to be used, but it is equally important that they be used right. The day of accidental or incidental classification is past. Either disposition of these lands with their varied values should not precede classification or the terms of that disposition must be such as to neither overlook nor disregard the possible results of future classification.

As a matter of fact, two methods of wise disposition of public lands are possible; the one would require the determination of the land's highest use as the antecedent and prerequisite of any transfer of title from the government; the other method would limit whatever title is granted so as to give recognition to known or anticipated land characters. Either system would in theory recognize the principle of land classification and express its purpose of ultimate full utilization, but in practice the one system necessitates official classification before use, while the other permits immediate development without endangering full utilization. The one method means delay, the other involves limited titles.

Current public-land legislation, whether we review recent enactments or read proposed bills, is seen to express this idea of full and highest use of the land and abandons the old policy of "land is land." The various separation Acts of the past few years permit the agricultural use demanded by present-day needs, without sacrificing the future utilization of the mineral estate. The procedure seems both safe and sane for the government to issue the limited surface title both where classification has shown the existence of two or more estates in the land and where future investigation not now practicable may be expected to develop mineral possibilities.

Classification of land is simply the determination of its natural values as fixed by the use or uses to which the land can be put. The practicability of land classification is contingent upon the quantity of facts available to the classifier. The elimination of coal land from non-coal land, or of irrigable from non-irrigable land, or of mineral land from non-mineral land, may possess all degrees of certainty and accuracy. So it follows that where an official classification is possible because of a fortunately adequate knowledge of its character, the highest utilization both present and future can be at once insured by the separation of the different values and by their appropriate disposition. If, on the other hand, knowledge of the land's resources is at best only imperfect or can be expected only in the course of future settlement and development, then the disposition of

known values for present use should not await formal classification, but future classification should be provided for by the issue of limited patents.

Classification of public lands and separation of estates wherever lands have a double value is simply the common-sense method of safeguarding public interest against fraud in the case of known or determinable resources and against speculation in unearned increments in the case of resources at present unknown or only suspected.

Land classification is a business policy that we should adopt as individuals, were we landed proprietors; as citizens having special technical acquaintance with the public lands and their resources can we advise any course of action less favorable to the interest of our fellow citizens?

The Disposition of Natural Resources

BY GEORGE OTIS SMITH,* WASHINGTON, D. C.

(New York Meeting, February, 1914)

In the utilization of natural resources owner, operator, and consumer should share the attendant benefits. Development needs to be planned under terms recognizing fully the interests of all concerned, for any undue advantage given to any one of these participants is apt to involve even greater and disproportionate injury to one or both of the others. For this reason it is well to preface any consideration of needed reforms in legislation affecting the disposition of public land with a survey of certain fundamental principles that determine the general conditions of all land transfers preliminary to development, utilization, and production.

The disposition of any undeveloped natural resource, whether timber, oil, coal, or water power, as a transaction to which land owner and prospective developer are parties, must be based in theory upon a division of expected returns. Whatever the terms of such disposition, neither party can reasonably ask for anything other than an equitable division of the returns. Under this analysis three and only three questions need to be discussed; namely, what are those profits, how is this division to be accomplished, and what is the equitable basis of division?

The answer to the third question should probably be found by applying to the problem the principles of theoretical sociology, and the question need not be mentioned further at this time, inasmuch as it does not involve the practical considerations to be kept in mind in connection with the other questions, which are concerned with only the measure of returns and their division. That is to say, whether the land owner's equity is to be stated as 95 per cent. or as 5 per cent. of the profits attending the development of the particular resource, no change would be necessary in the method to be adopted of arriving at the closest approximation of the prospective total profit.

If on this basis we now compare the two methods of disposing of

* Director, U. S. Geological Survey.

land valuable for its natural resources, sale and lease, we shall discover a somewhat regular variation in the degree of approach to the ideal determination of actual profits and accomplishment of their definite division. The sale of an undeveloped resource is predicated upon an advance estimate of its prospective value for purposes of development, and whatever the theory of division of its appraised value between the land owner and the operator, there will exist a certain element of risk which necessarily involves the possibility of disproportionate profit or loss to either party and which naturally will be discounted by both. We must recognize that the risk thus created becomes a legitimate if not absolutely necessary basis for an additional item of cost in operation and therefore will tend to increase both cost and selling price; so that if at this point there is introduced the third party to all such transactions, namely, the ultimate consumer, we discover who pays the carrying charge of this risk. This added item of cost may appear in the preliminary financing in the form of a larger interest rate offered to the bondholder, or of a larger discount given to the underwriter, or of a larger dividend promised to the stockholder, or in all these combined.

The uncertainty in the valuation of undeveloped resources may be illustrated by citing that of coal estimates in unexplored territory, it being a common experience of engineers either to overestimate or to underestimate the tonnage, even after preliminary drilling of the tract under consideration.[1] As a means of obviating this uncertainty so far as the amount of payment to the land owner by the operator is concerned and of permitting a more equitable sharing of the attendant risk, the advantage of lėase over sale becomes apparent. In timber lands the benefits of operating under lease are of similar nature.

The charge paid by the operator to the land owner under leasehold may be figured at either a fixed or a variable rate. If fixed, the charge may be either one based upon the area of the land involved, in which case it is termed rent when paid periodically or bonus when paid in a lump sum, or one determined by the quantity of the product of the land, in which case it is termed royalty; or the compensation may be fixed by a combination of the two methods. Rent and bonus are in a measure unfair, or at least less equitable, in that they involve no direct account of the extent of actual use, while, on the other hand, royalty is dangerous in that it sometimes places a premium on speculative non-development or non-use in furtherance of

[1] The difficulties attending even the most painstaking efforts to estimate value or predict profits are best set forth in the contribution of Dr. Chance, Valuation of Coal Land, at the Butte meeting of this Institute, *Trans.*, xlvii, 111 (1913).

monopolization. A combination of the two becomes advantageous, wherein the rent is made a penalty for non-use but is remitted whenever an equivalent royalty is being paid.

Royalty, expressed as so many cents or dollars per unit of the product, fails to provide the proper division of profit in that it neglects full consideration of the varying value of that product. To conform to such variation with either time or place the royalty itself should be variable, and it may be made so by a variation in terms whereby the royalty varies, for instance, with stage of development and thus indirectly and somewhat indefinitely with cost of operation, an arbitrary method of securing a definite sharing of the expected profits; or the rate may be made to vary with market price of product, as in iron ore leases, wherein there is a fixed basal royalty with an increment dependent upon the current market price of ore. Or, better, the variation may be made to coincide automatically with the changing value of the product by making the royalty one in kind, as is the common practice in petroleum leases, where the royalty is a stated fraction of the output. Yet even this better form of variable royalty itself falls short of the ideal by its lack of consideration of the important element of cost of operation, although of course it takes full account of the varying selling price. If these methods of varying the royalty with changing cost and price are combined a nearer approach to the ideal is attained, as, for instance, if the fraction expressing the royalty should be decreased as cost goes up or as gross receipts go down. An illustration of this may be seen in the advantages that would accrue in the case of an oil pool having a steadily decreasing yield, where the royalty fraction should be proportionately decreased, thus affording the operator a continuing profit—sufficient to warrant his continued pumping rather than forcing him to abandon the field. On the side of the land owner, receipts would continue over a longer period and aggregate a much larger amount, even if the royalty rate was successively decreased from $\frac{1}{6}$ to $\frac{1}{8}$ to $\frac{1}{10}$ to $\frac{1}{12}$ to $\frac{1}{16}$ or even to $\frac{1}{24}$. Even more important would be the public advantage of obtaining from the pool a longer continued and larger aggregate production. Such a form of royalty would therefore be most conducive to conservation, in the benefits of which land owner, operator, and consumer would all share.

All these variations in the terms of the leasehold are simply methods of attaining a division of profit between owner and operator; that is, they have one and the same object: namely, the equitable division of the value of a resource as it is being developed. They all fail, however, of attaining their object in whatever degree they neg-

lect to take into account all the elements that determine and limit the ultimate profits: namely, varying cost, varying output, and varying price. Commonly at least one of these factors is either omitted or at best only roughly estimated in advance. In this way the division actually becomes more or less a division of gross receipts, so that it logically follows that a better result should be secured directly by the division of net returns.

Under a lease of this ideal type the return to the land owner would be, not a royalty either fixed in amount or even variable with both quantity and value of product, but instead a royalty defined in terms of a fractional interest on the part of the land owner in the net returns of the operation. This, in short, would be a partnership similar to cropping on shares by a farm tenant. If the operation produced negative results the operator, as the one more directly responsible, should probably bear the whole monetary loss, the land owner on his side having lost his share in a possible value of the resource under other management. It would seem also to follow that in this type of lease the fixing of a time limit would become unnecessary. Changing conditions, whether physical or social, need be neither predicted nor discounted to preserve the equities of either party, so that the lease could be indeterminate in form, its life being dependent upon only the permanence of the resource or of the market for the product.

Two objections to the practicability of this method will at once be suggested. First, the difficulty in the land owner controlling the efficiency and economy of the operation. He has, however, two means of influence: the one direct, namely, his choice of the lessee, and the other indirect, namely, the fact that the owner's returns and the operator's returns will be proportionate, so that it is to the operator's interest, as well as to the owner's interest, to obtain the largest possible net returns. The second objection, which has a larger basis in fact, is the difficulty of insuring both an honest and an accurate accounting.[2] Here, however, the only answer is one based upon an optimistic outlook on present tendencies in business. The trend is unmistakably toward uniform and public accounting. The requirement of open accounts in which well-recognized methods of accounting must be adopted will prevent in large measure not only any misrepresentation to the land owner but also—what is equally important—the imposing on the consumer of a price involving an over-

[2] Veatch reports that in South Australia, where a royalty of 2.5 per cent. on net profits has been in effect in leases for half a century, the practical difficulty of ascertaining net profits is regarded as insurmountable. *Bulletin No.* 505, *U. S. Geological Survey*, p. 62 (1912).

large profit to the two partners, the landlord and the operator. Such an element of possible graft as fattening the pay roll with inefficient and overpaid officials, perhaps related to the operator, could be prevented by conditions in the lease. Inasmuch as the operator's equitable share of the returns commonly would be by far the larger share, the inducement to this form of petty graft would not be so great in practice as would at first glance appear likely.

Thus far the landlord considered has been the private or corporate land owner. If the government is the landlord other factors enter into the problem, without, however, affecting the force or applicability of the principles already set down. Here the government, as the lessor, is acting in a dual capacity: namely, that of landlord and that of representative of the consumer. The larger public interest in the lease may thus relate to beneficial control of operation and production rather than to the revenue involved in the operation under the lease. The sharing between the owner and operator of the ultimate value of the resource developed has as its purpose the increasing of the ultimate return to the public, which may come in one of two ways, directly by increasing the royalty or indirectly by keeping down the price to the consumer. In certain cases, moreover, a low royalty rate, with low price, might stimulate consumption to so great an extent that it would yield an aggregate larger royalty than would result from a higher rate, thus giving a double benefit to the public.

The difficulties attending a valuation of government land for sale largely arise from the fact that the government has this double rôle. As the representative of the people the administrative officer hesitates to put so high a valuation upon the resource as to hinder its development or directly affect the cost and selling price of the product. Thus in the valuation of public coal lands, for instance, every element of uncertainty is resolved by the official representatives of the public in favor of the prospective buyer. Under leasehold these uncertainties as regards quantity of resource would disappear, for the royalty is paid only as the resource is developed. If the royalty be made to vary with net returns from the operation, so that the charge is determined as the result of actual division of profit, it will follow that the public, in its capacity as landlord, will get back a proportionate part of whatever it, in its capacity as consumer, pays for the product over and above the actual cost. In this sense the development of the natural resource will be put on a purely co-operative basis.

In the recently approved permit for the utilization of water power on Pend d'Oreille river or Clark fork of the Columbia, the use of

Federal lands is conditioned upon prompt construction and installation, with no charge during the period of development of works and of market. After 10 years the rate of compensation to the government varies inversely as the square of the proportional development of the site and directly as the square of the average price charged for electric energy to both customers and consumers. While protection of the ultimate consumer is the purpose of these terms, the return to the government, as will be seen, is determined by the receipts of the operator. Furthermore, since operating costs doubtless vary within a smaller range than selling prices, this royalty, which varies with the square of the average price, becomes one based more nearly upon net profits than upon gross receipts.

As applied to the development of any natural resource belonging to the people the practical effect of a leasehold plan wherein the royalty would be a certain proportion of net returns resulting from the development of each particular resource will be threefold: 1. A certain part of the element of risk will be eliminated, thereby making possible a lower factor of safety in the operation finances, so that the cost can be reduced, to the possible benefit of the consumer; at least there will be one less reason for excessively high prices to the consumer. 2. Any false excuse for exorbitant prices to the consumer will be prevented by open books. 3. An equitable sharing of profit between the owner and the developer of the resource will be possible because, with the relative equities between these two partners determined, that division of profits will be applied directly to actual returns rather than to estimates representing long-range predictions or only partial determinations.

The present-day tendency is to recognize more and more the public-service nature of great industrial developments. Governmental regulation is not only an accomplished fact in intraurban as well as interstate transportation but is rapidly becoming a realized ideal in the conduct of other corporate business the products of which constitute the necessities of life. Thus the combination of public ownership and private operation in the utilization of natural resources, such as the great supplies of mineral fuels and fertilizers or of timber or of water power remaining in public ownership, may be regarded as simply a logical phase of present-day progress. With the government as a partner, possessing a common interest in the profits of development, the individual or corporate operator should expect sympathetic co-operation and a minimum of administrative supervision, with its attendant evils of unnecessary overhead charges and costly delays. We might even attain that ideal of production which accomplishes the lowering of prices by keeping down costs.

Discussion

Continued Discussion of the Author's paper on Our National Resources and Our Federal Government (*Trans.*, xliv, 612), and Discussion of the paper of George Otis Smith on The Disposition of Natural Resources, p. 430.

R. W. Raymond, New York, N. Y.—The propositions contained in my paper above mentioned were denied, in whole or in part, in communications to the Secretary from Messrs. R. B. Brinsmade, Pueblo, Mexico; G. W. Wepfer, Berkeley, Cal.; and George Otis Smith, Director of the U. S. Geological Survey.

Mr. Brinsmade, agreeing with me as to the desirability of local, rather than Federal, administration, and as to the evils inseparable from the Federal "apex law," dissents from my "four final propositions," for reasons given in addition to those stated by Director Smith.

These four propositions were in substance: (1) that governmental interference with private enterprise is in general undesirable; (2) that, if necessary, it should be performed by a municipal or State, rather than by the Federal, government; (3) that a certain system of leasing (which I defined) is the worst that could be adopted by any government; and (4) that the argument for Federal leasing of the coal lands and water powers of the public domain would be equally strong for a similar treatment of other mineral, or even of agricultural, lands, concerning which we had heard, at the time I wrote my paper, practically nothing from the advocates of the new Federal policy. At least, such an extension of the new plan of Federal control had been explicitly disclaimed by President Taft, in a public address, advocating that plan for coal lands and water powers.

Mr. Brinsmade explicitly approves my second proposition, and does not explicitly condemn my first. His opposition to the third (apart from arguments like those of Director Smith, to be considered later) seems to rest upon an economic theory as to the private ownership of land, which I must decline to discuss here. It is an old theory, as familiarly known as it is frankly rejected by the best authorities. But it is not pertinent to this discussion, because it attacks the ownership of all land whatever.

It is "on the basis" of this economic theory, that Mr. Brinsmade disputes "the assertion of Dr. Raymond that our railroad land grants and mineral-land laws were essential to the settlement of the West." I did not use the word "essential," and I plainly said that the result referred to might have been reached by much longer processes. But the difference is trivial; and the facts are incontrovertible "on the basis" of any theory whatever.

As to my fourth proposition, Mr. Brinsmade claims that it has already been answered by many foreign countries. Perhaps I am to blame for his misunderstanding of my statement, which referred exclusively to this country, where the doctrine of the governmental ownership of all property, apparently approved by him, is advanced by a party not yet venturing to carry it to its logical result, and therefore confining it, for the present, to certain kinds of property, called National Resources. I am grateful to Mr. Brinsmade for his through exposition of the doctrine and its ultimate results.

Mr. Wepfer describes the government leasing system of Bolivia, which is quite unlike the system I characterized as bad. According to his account, any one, citizen or foreigner, can acquire in Bolivia for $1.66 per acre a patent to mining ground of which he holds exclusive possession so long as he pays semi-annually a tax of 33 c. per acre. This is practically a purchase of the ground. The forfeiture of ownership by non-payment of the small tax constitutes no hardship. Continuous working is apparently not required. The revenue from the tax must be insignificant —scarcely enough to cover the cost of collection.

To my argument that it would be unwise for the Federal government to treat the different States differently, Director Smith replies only that there has been for the past half-century an evident tendency to expand Federal functions, and that it is only "national" resources that the national government is to administer—and specifies the mineral wealth of the public lands as an illustration. My rejoinder is simple. I admit the existence of such a tendency as he asserts; and I recognize that it has been largely created and augmented by the zeal of enthusiastic heads of Federal departments; but I believe it to be dangerous and unwise.

In emphasizing the all-important distinction between the landlord and the sovereign, and showing that in dealing with the public mineral lands, the United States has acted as the owner, not as the sovereign, I have hitherto tacitly assumed that the ownership of the United States was as complete as that of any private owner of the common-law fee-simple, covering both the surface and the minerals beneath it, and conferring the right of perpetual possession, free administration, lease or sale of both together, or of either separately. For the purpose of my argument, this was sufficiently accurate; for the mineral-land laws under discussion looked to the sale of the lands only. But now it is frankly proposed that the United States shall no longer sell these lands, but shall hold and lease them for the benefit of the Federal treasury. This warrants a closer inquiry into the history and nature of the "ownership" of the public lands; and such an inquiry discloses some interesting facts. Perhaps our fathers did not know as much as we do; perhaps their promises are not binding upon us; perhaps their institutions are not worthy to stand against our "tendencies." Nevertheless, we can afford, in our superior strength and wis-

dom, to learn what we are undermining or overthrowing, or even simply (but not less destructively) ignoring.[1]

The well-known origin of our public domain, through the cession of Western lands by certain of the original States, was the result of an agreement, ending a long controversy, consummated before the adoption of the Constitution, and confirmed in that instrument. In that controversy, Virginia, the steadfast champion of State sovereignty and opponent of imperial domain, refused, against great pressure, to consent to the transfer of unconditional ownership of the lands in question; and, after a proposition made by Congress in 1780, submitted her own counter-proposition, which was agreed to by Congress in 1783; and March 1, 1784, the deed of Virginia was accepted by Congress. This deed transferred all the rights of Virginia on conditions which made the Federal government, not absolute owner, but trustee, authorized to administer the public lands for the benefit of all the present or future States of the Confederation, but bound to dispose of them so that they should be settled and formed into distinct republican States, and as such admitted into the Federal union, with the same rights of sovereignty, freedom and independence as the other Sates.

The deeds of other States, held back to await the decision of Virginia, were subsequently executed; and the Confederation thus became holder in trust of the public domain, on the conditions which the wisdom and courage of Virginia had imposed.

The Convention which framed our present Constitution came some years later (1787), was subordinate to Congress, and was required to report to Congress; and the provision of the new Constitution, relating to the public lands, was framed in conformity with the Congressional ordinace of 1787, and confirmed the contract with Virginia, by declaring that nothing in the Constitution should prejudice the rights either of (1) the United States, or (2) of any particular State. The former rights covered the profit which the United States might realize from the public lands before their sale or through their sale; the latter rights were those of the grantor States to insist that the one and only purpose of Federal management should be the sale of the lands and the formation of new States.

I think no competent student can deny that the title of the United States under the new Constitution was the same as under the preceding Articles of Confederation, and that, whatever its exact nature, it forbade the adoption of any system of Federal administration looking to the

[1] The following statement, based upon an address on The Status of the Public Lands, and Its Relation to Mining Tenures, by George T. Edwards of Berkeley, Cal., delivered before the San Francisco section of the Mining and Metallurgical Society of America, and published in the *Bulletin* of that Society, No. 57, vol. vi, No. 2, (Feb. 28, 1913), I have verified by reference to original sources.

permanent Federal ownership of the public lands. Refined subtlety of construction as to the language of these documents is out of place; for the old common law still governs us in the interpretation of contracts according to the intention of the parties; and concerning this intention there is no doubt. Virginia victoriously maintained, Congress finally accepted, and the new Constitution ratified, the principle that no great tracts of land, held by the central government, should ever prevent the formation of new sovereign States, or impair the power and rank of such States. If further confirmation be needed, it may be found in the decision pronounced by the United States Supreme Court in 1845[2] concerning certain public lands in Alabama, which declares:

"The United States never had any municipal sovereignty, jurisdiction, or right of soil in and to the territory of which Alabama, or any of the new States were formed, except for temporary purposes, and to execute the trusts created by the acts of Virginia and Georgia legislatures, and the deeds of cession, executed by them to the United States, and the trust created by the treaty with the French republic, of the 30th of April, 1803, ceding Louisiana. . . . When the United States accepted the cession of the territory, they took upon themselves to hold the municipal eminent domain for the new States, and to invest them with it, to the same extent, in all respects, that it was held by the States ceding the territory."

This decision goes far. It declares that even the territory acquired by the Louisiana purchase, like the land previously ceded by some of the original thirteen States, is held by the United States as a trust for the creation and endowment of new States. In the treaty of 1803 with the French republic, the United States guaranteed to the inhabitants of the ceded territory the same rights as were guaranteed already by the Constitution to the inhabitants of the existing public domain.

But in the argument which Director Smith opposes, I did not go so far as to assert that the Federal administration which he advocates would be unconstitutional. I contended only that it would be unwise, as a matter of statesmanship. And I am still content to stand upon that ground. Whatever the legal or historical reasons, the fact is, that the public domain conveyed by some of the original States has been treated according to the contract made with them; that the State of Texas was admitted by treaty, with its own public lands and land laws, and entirely free from any claim of the United States over any one of its "natural resources"; and that hitherto, the policy of the United States, as expressed in its legislation, has been to carry out, whether it was or was not legally bound so to do, the policy established in 1784, and then expected to be permanent—namely, that of administering the public domain for the purpose of having it occupied, as soon as possible, by citizens owning it; of forming out of these citizens, as soon as practicable, new States, and of leaving to

[2] Pollard's Lessees *vs.* Hogan (3 How., 212), cited by Mr. Edwards in the paper already mentioned, and consulted since by me.

these new States, as a source of revenue, the taxation of the wealth produced from their natural resources.

What Director Smith and his party propose ought to be acknowledged as at least new. They propose that instead of selling "national resources" to private citizens, and thereby making them taxable by individual States, the Federal government shall hold on to them and lease them—not for the appreciable direct advantage of the Federal treasury; nobody dreams any such wild dream as that—but for enough to pay the cost of Federal "administration" and experimentation, leaving the State to get what revenue it can by indirect taxation.

The State of Texas is already looming up as a formidable rival of its sisters in the Union. Its immense area; its varied natural resources; its climate, favoring all industries; and, above all, its complete immunity from Federal control (whether in the name of "conservation" or in any other name) of its own self-directed internal development, are making it more and more portentous. Whatever may be adopted as the policy for administering United States public lands in other States will not apply to Texas, which contains no such lands.

I venture to say that any legislation which handicaps other States, by reason of their history, while it excepts Texas by reason of its history, is bad statesmanship. I know that the theoretic right of secession from the Union was disproved by a terrible war; but I am equally sure that the peaceful and prosperous maintenance of the Union requires a just and equal treatment of the States which compose it. Whether the people of a given State resort to futile armed rebellion or not, is a subordinate question. The main question is, do they feel that they are justly treated?

The policy established by our fathers in the contract with Virginia and other States, whether it be or be not, with regard to all the territory subsequently acquired, legally binding upon us, solves this problem. And that is why I say, independently of all legal and constitutional argument, that the revolutionary novelty of permanent Federal ownership would be bad statesmanship.

Director Smith objects to my contention that local, instead of central, government should deal with local interests and industries, asserting his belief to the contrary. But I am of the same opinion still, though I abstain, for the present, from advancing further proofs of my proposition, which might involve invidious criticism of friends in official positions, whose loyal labors I am not inclined to disparage. Yet I must be permitted to say in general terms, and without personal references, that I have seen in no department any proof that government employees are specially qualified to supervise the operations, solve the problems, or prescribe the models for individual enterprise. This general statement covers State as well as Federal activities; but with reference to the distinction between them, I will add that, within the last ten years, at least

two of the Federal executive departments have been guilty of errors which have escaped the condemnation they deserved, and would have received, if they had been perpetrated in the service of a single State. What I know of Federal administration has convinced me that it is less desirable than State administration, and that either of them is less desirable than individual enterprise under ordinary legal responsibility, as a means of securing the benefits of public prosperity and social justice which the advocates of all these systems profess to seek.

Director Smith defends the leasing system on sundry grounds of economic theory, and by appeal to the experience of other nations. I must postpone to some future occasion the thorough discussion of that subject. The most important feature of the present situation is the circumstance that the intelligent and patriotic official head of a great and useful Executive department, now frankly advocates this system for all the mineral resources of the public domain. I, for one, welcome this declaration as a substitute for the piece-meal suggestions of exceptional treatment for special "resources," like Alaska coals, or phosphate lands, or possible deposits of radium. Let us have the full plan of Federal control at once, and know what we have to face!

It is hardly necessary to assure us that the proposed leasing of "national resources" would be done rather for public benefit than for public revenue. Past experience, as well as common sense, assure us that the expenses of inspection and regulation would quite absorb, if they did not exceed, the net revenue of the system. Indeed, those of our States which possess no resources on which the Federal government can at present lay its helping hand—a large majority, in fact, of those which constitute the Union—might count themselves fortunate in such an event, if they did not have to pay their share of the extra expense of the blessings governmentally bestowed upon their less fortunate sisters.

Director Smith corrects what he regards as an inadvertence on my part in my statement that the advocates of a leasing system contemplate the requirement of continuous operation, and adduces to the contrary a passage from his annual report of 1911, referring to needed legislation for oil lands. My statement was based on a plain declaration of the President of the United States to the effect that "natural resources" should be leased by the Federal government on the condition of continuous utilization of the privilege granted. I had not read Director Smith's report; but I do not see that his plan for oil leases offers anything essentially different. Instead of punishing the suspension of production under lease by the forfeiture of the lease, he would make the "ground rental sufficiently high to discourage the acquisition of lands except for immediate and continued development," and he says that "this indirect control of development would be preferable to the direct enforcement, by forfeiture, of continuous production, which should be avoided because of

the danger of disturbing the delicate equilibrium between supply and demand."

As I understand this statement, the high ground rent is expected to discourage the holding of oil land without producing oil from it. On the far greater and more immediate evil of reckless overproduction and consequent irrevocable waste, it would have a contrary effect, if it had any. It would be much more practical to lower the rent for a tenant who was prevented by the delicate operations of supply and demand from producing oil at a profit, and thereby encourage him to assist the government in conserving the oil until a rise in market price showed that it was needed. But most practical of all would it be, to let the aforesaid equilibrium between supply and demand (the variations of which, though delicate, are irresistible) take care of the whole matter. For it operates by the old-fashioned law of gravity, with which, when it is acting in our favor, we can often best co-operate by letting it alone. But I did not intend, in this reply to Director Smith's criticisms of my paper, to wander into a discussion of his own later utterance; and, indeed, I would not have mentioned it had he not called attention to it in his remarks. The question presented by the petroleum lands is in many respects peculiar, and deserves separate consideration.

An Oil-Land Law

BY GEORGE OTIS SMITH, WASHINGTON, D. C.,

(New York Meeting, February, 1914)

Introduction

THAT an oil-land law is the most needed item in the proposed program of mineral-land legislation follows from the fact that Congress has never enacted a law really applicable to petroleum and natural gas. The action of Congress in 1897 in authorizing entry of oil lands under the placer law, enacted 27 years before for the mining of gold in surface gravels, was plainly only makeshift legislation. Naturally the provisions of this placer law with its requirement of discovery as a prerequisite to location are nothing less than absurd when applied to petroleum deposits hundreds or thousands of feet beneath the surface. Other reasons which render oil-land legislation an urgent necessity arise first from the large acreage of lands believed to be valuable for their deposits of oil and gas and therefore withdrawn by Executive order from all entry pending the enactment of an appropriate law for their disposition—a withdrawal that has been specially ratified by Congress in the case of one State, Utah—and second from the exceptional importance of this resource to the nation, the large industrial worth of petroleum, and indeed its paramount value to the navy, not being suspected 17 years ago when Congress last legislated upon this subject.

Mineral land of this type is also well adapted to serve for purposes of illustration in discussing the general principles that demand recognition in legislative reform. Most of the issues involved in the consideration of oil-land legislation are clean-cut, and essential differences of opinion will be seen to be based upon radical divergence in economic theory rather than upon conflicting views concerning unimportant details.

For the last five years or more the geologists of the Federal Survey have discussed this subject and prepared memorandums and reports on the various bills introduced in Congress. Most of the provisions suggested in the present outline have been under consideration at one time or another during that period, and many of the statements which follow can be said to represent the consensus of opinion among those of us who, both in the field and in the office, have given special attention to the public oil lands.

Purpose

Stated concisely, the purpose of an oil-land law should be to promote development, with the aim of insuring the highest percentage of extraction at the lowest cost to the consumer, and during the longest period consistent with fully meeting market demands. This is a somewhat complex ideal, in that it includes full recovery, minimum costs, and production responsive to the market; yet these are the practical ends to be desired by operator and public alike.

Except in the special case of certain limited areas, now selected from the larger reserves which were originally set apart for the Federal purpose of insuring a future oil supply for the use of the American navy, there should be no idea of reservation of this natural resource in the sense of postponing its use. We know that the present generation needs fuel oil, gasoline, kerosene, and lubricating oils. On the other hand, there should be no artificial stimulation or encouragement of speculative activity, such as will lead to overproduction and waste; for we may expect that other generations will need, and will make good use of, whatever petroleum deposits we leave undeveloped.

An oil-land law should aim to permit full regulation of development rather than to provide large revenues. Not profit but control is the primary purpose; and the beneficiary of wise legislation is to be the public in its capacity as consumer rather than as taxpayer. With low prices as the desired end, and low costs as the necessary means, caution should be exercised not to saddle upon the development any conditions or terms of land tenure that will involve unnecessary burdens.

To meet this purpose of public control—control only as a means, not an end in itself—the leasing system is pre-eminently the logical one; and its applicability to the oil lands remaining in public ownership is not a matter of theory; for the traveler in the California oil fields needs only to look in any direction from the withdrawn areas to see adjacent lands to which the government has granted patent being operated under leasehold. There is no possible difference in either theory or practice between leasing public oil lands and leasing private oil lands, except that in the former case the public shares in the profit as landowner, and should also write into the lease conditions that are favorable to successful development and that therefore permit prices satisfactory to the consumer. In the long run, low costs can come only through successful operation; and, to be successful, oil production, like other business ventures, needs to be attractive to the highest type of operating skill, backed by not over-timid capital. Thus fair profits to operator and just prices to consumer are far from being antagonistic elements in the proposition, but on the contrary are essential to the ideal results sought. Some of the conditions favorable to safe and economic development will now be discussed.

Conditions Promoting Development

First, any oil-land law, whether providing for disposal of the land by sale or of the deposit by lease, should contain a provision granting exclusive occupancy for purposes of exploration. Prospecting for oil involves large expenditures; and the inherent defect of the old placer law, when applied to oil land, was this absence of protection prior to discovery. The area necessary to encourage this expensive exploration and the period essential to its accomplishment are details to be determined, with the recognition that geographic and geologic differences exist which render advisable some latitude in administering different fields, so that a maximum area is all that should be fixed by law. There should be kept in mind also the need on the one hand of enforcing purposeful endeavor and yet on the other of avoiding any requirement of non-productive "assessment work." The prospecting permits would terminate by forfeiture because of inadequate prosecution of development work or by failure to discover oil within the statutory period, or, in the case of discovery before its expiration, the permit would ripen into a lease.

The area to be covered by the lease must necessarily be the whole or a part of that included under the preceding permit, the granting of the larger area being possibly a wise method of rewarding a discovery of the "wildcat" type. The period of the lease could be indeterminate, the life of the pool furnishing the natural limitation upon the period of operation. Requirements of drilling should be liberal enough to provide little more than what would constitute the natural response to market conditions. A more stringent requirement, however, should be that of compliance with all waste and water regulations imposed under the police power of the State.

Terms of Lease

Recognition by the lawmaker of the existence of large geologic and commercial differences in oil fields should lead him to fix the rate of royalty only within wide limits, or leave it wholly to executive discretion. Further, as market prices and operation costs may both be expected to change, provision needs to be made for a varying royalty rate. Thus, with the declining yield of any particular pool, unless there should be a corresponding increase in price, the point would be reached when the margin between cost and receipts would disappear, even before the wells ceased to yield oil, so that further operation would require a reduction in royalty rate. This type of a sliding royalty would permit the largest possible ultimate yield.

Even though not fixed for the purpose of revenue, the royalty rates in the developed fields would approximate those fixed by private lessors,

so that the returns from public oil-land leases might be large, and could well be divided between National and State treasuries.

Prevention of Monopoly

The primary purpose of low cost to the consumer may not be attained by simply keeping down production cost, unless some measure of safeguard is provided against the possible results of monopoly. Agreements between operators either to restrict production or to raise prices may be prevented in two ways under leasehold. Transfer of lease should be conditioned upon the approval of the Secretary of the Interior, and an anti-combination proviso in the lease should carry the penalty of immediate forfeiture of the lease, allowing, however, the opportunity of a court appeal, the government to be secured by bond for the full value of the oil produced during the period covered by the litigation.

Another condition in the lease that might be thought to possess a beneficial influence on prices would be, with the royalty under an oil lease in theory a royalty in kind, the reservation to the lessor of an option to take the oil itself rather than its equivalent at market prices. If a large acreage of public oil land were operated under lease, the government itself might thus be one of the larger possible factors in the market and exercise a positive influence in keeping prices expressive of true conditions of production rather than of a manipulated market. At least, if the government could not thus protect the general public, it would insure its own supply for Federal use.

Résumé

An oil-land law should provide for exploration under a permit which fully protects the prospector, and for operation under a lease which favors the operator by a reasonable royalty adjustable to actual conditions, and by provisions which permit low costs but prevent the imposition of unduly high prices on the consumer.

Discussion

Eugene Coste, Toronto, Canada.—I am interested in what Dr. Smith has said, and in the fact that you are working earnestly in the United States toward a good oil-land law, which is certainly very much needed. Nothing could foster the oil industry in those parts controlled by the Federal government more than a good law.

I would like to make one or two objections, if I may call them so, to Dr. Smith's statements. He is, I think, in favor of making a too-complicated law. I would prefer a simple law, rather than one that is complicated, even though it is not so good. The fact of its simplicity makes up for its imperfections. I do not see the use or necessity of first issuing a permit to prospect oil lands and then afterward a lease. You cannot explore oil land, except in the one way, by drilling wells, and therefore I think it would be better for everybody concerned if the law were such that an applicant could get his final lease promptly without going through the form of getting a permit first, the lease for which land may not be issued later. You cannot expect any one to spend much money on simply a prospecting permit, his title not being sufficiently secured.

I will cite an instance of that. In Canada we have regulations; not law regulating Federal land, but Orders in Council; that is, the government makes certain regulations, called in this case "Petroleum Regulations." Up to a short time ago an applicant could tender $5, and he could hold up 1,920 acres of land for one month. During that month he had to pay 25c. an acre, and then he would get his lease. A lot of speculators took advantage of that provision, and paid $5, never intending to pay the 25c. an acre, just to have a sort of a title for one month, and they would hold up the *bona fide* oil men who wanted to get the land for drilling. Thousands upon thousands of acres were plastered in that way.

The Interior Department got into such a tangle that they finally saw the point which I had brought to their attention vainly years before, and they now have changed the regulations; now you must pay 25c. an acre at the time you make your application for the land, and this payment insures one an absolute title for 21 years, and is renewable for another 21 years, provided, of course, one meets the other obligations of the lease. There is no doubt that this new regulation, which insures one a good title lease right in the start, and which will prevent the speculator from coming in and holding up oil lands, will be much to the benefit of the *bona fide* operator who intends to spend thousands of dollars on his lease. All he wants is to get a simple but safe title, with no provisions left to the administrative officers to decide whether he will be permitted to go on after spending much time and money. Law is made by Congress here, and I should have no such matters left to the discretion of departmental or governmental officers; and anything that arises in the way of dispute should be settled by judges in the courts.

While this is true, the law should incorporate all the safeguards possible. And whether there should be a royalty or a rent paid, it matters not. It works well both ways, and makes very little difference. But there should be a strong condition of drilling, so that there would be no mere speculation. In Canada the government remits the second and

third years' rentals, which are 50c. an acre, on proof that more money than the rentals due has been spent in drilling. There is no royalty; on the contrary, the government is offering a bounty. The remittance of the second and third years' rentals, if you can show that your expenditures have at least equaled these rentals in the work of actual drilling, is a good provision, as it lets you put your money into wells, which are, of course, the ultimate source of all wealth in oil fields. Besides there is a compulsory provision in the leases that you must be drilling a well on every three sections after 15 months from the date of the lease.

David T. Day, Washington, D. C.—I want to ask one question of Mr. Coste. In this country we are becoming embarrassed by the foreign ownership of American oil lands, and it is generally understood that some protection is being arranged in the disposal of Canadian land by regulation or by law. I would like to hear something on that point.

Eugene Coste.—The changes made in that respect are so recent that I am not quite certain of their purport. But I think the only change that has been made lately is that there are provisions that the Board of Directors of a company acquiring oil lands from the government should have a majority of their members residing in Canada, and a few matters of that kind. In the recent regulations the majority of the Board of Directors must even be Canadians or Englishmen. A similar provision was already in the laws of the Province of Ontario. While I am speaking about oil laws and mining laws I might remark that in Canada we are in about the same fix as you are here in regard to our mining laws. That is, I mean the Federal laws. We have had good laws in the Province of Ontario and the older Provinces, but in Saskatchewan, Alberta, Manitoba, and the Northwestern Provinces, which are still under Federal law, we have as yet no mining law, and we have only regulations by Order in Council. That has been most detrimental to the industry, and very hard on mining men, as these regulations are made by a clerk in the office of the Department of the Interior who knows nothing about mining and are then passed on through the Minister of the Interior to the Council, and the result is that you have something that is absolutely ludicrous, just like the provision mentioned above where by paying $5 one could get 1,920 acres of land from the government, and hold it for a month, and after that month lapsed he could pay another $5 and hold another 1,920 acres for another month. Then five or ten people could get together and hold these lands from month to month simply by paying $5 a month for each 1,920 acres. Some definite, clear and simple title lease for the *bona fide* applicant who really wants to go to work, at so much an acre, with drilling provisions, is all that is wanted. But for these operators the title should be absolute, without any possibility of impeachment. If I had my way the leases issued would be only a half page in length, giving the applicant

title, absolute title, and requiring from him so much rental per acre, and so much work in drilling, and that is all.

HENNEN JENNINGS, Washington, D. C.—I think Mr. Smith was with us yesterday when we discussed mining laws, and the confusion and uncertainty that have arisen in connection with the laws of the apex. I think unintentionally he is putting elements of uncertainty in these suggestions which may develop troubles akin to those which were discussed yesterday.

I am entirely sympathetic with a lease that is in the nature of a practical ownership, that people can rely upon. But I do not believe in backing and filling or giving the government any power to back and fill in dealing with people who start to develop a large enterprise. You should make up your mind as to what the government is willing to do at the start in a given locality; and if you want a lease system, make it fixed and determined, and not leave it to the discretion and periodic adjustment of officials; it was shown yesterday in our discussion, that even with honesty of purpose and ability the scientific opinions of men vary as knowledge increases and facts accumulate.

I entirely agree with the fundamental aim set forth by Mr. Smith, that the consumer should obtain the oil at a minimum price, but with minimum waste.

The gentleman who has just spoken [Dr. Coste] of the Canadian practice seems to be perfectly sound in his recommendations, and they are in accordance with the practice which I have been accustomed to see work most satisfactorily on a large scale in South Africa. The leasing system of the gold mines in South Africa is a definite thing. You know your rights and risks from the start and your lease is negotiable. You are prevented from tying up land for speculative purposes by a definite fixed monthly charge per claim area. The area under exploitation pays a higher license than the ground unworked, but this has a lease tax that makes it a burden and detriment to hold unless provision is being made for its early exploitation. Why is not a similar system possible and desirable in petroleum leases? Make the area of holding generous, but with constant fixed, unalterable term payments for all ground held, whether worked or not, and with a definite but not excessive royalty per barrel for all oil extracted. The royalty might vary for each district, but when once fixed it should not be changed.

I will not go further into detail, but I will ask Mr. Smith to consider the possibility of amending his suggestions to meet some of the views which have been expressed.

GEORGE OTIS SMITH.—With regard to the suggestion by Dr. Coste and also the suggestion from Mr. Jennings, I agree that we should have a simple law which should lead to a simplified contract. I have suggested a law that in certain terms might vary with different conditions.

I have not suggested a contract which would vary after the contract was entered into; except that I have suggested a sliding scale of royalty in order to protect, not the government but the operator.

It would be a sliding downward scale, in order to continue operation under more favorable circumstances, rather than to force the stoppage of oil production because it would not pay the cost of production plus the royalty, as fixed in the contract. I do not believe there is any suggestion made in Washington to have anything less definite than the ordinary contract which is made in business.

I absolutely agree with Mr. Jennings. I said in my paper yesterday that any uncertainty involves an unnecessary expense in operation and financing, and therefore it should be avoided. The reason for having a permit, and having it followed by a deed, is because a prospecting permit should be for a larger acreage than that which is to be written into a lease.

The suggestion under consideration by the Secretary of the Interior, and by the Chairmen of the two Congressional Committees, referred to by Senator Walsh in yesterday's session, is to provide a permit for an area which will be four times the grant to the successful prospector. In other words, if you take 640 acres under a permit, you will receive in fee simple title to 160 acres; the remaining three-quarters of the square mile being available for leases under definite terms, fixed by the government, by or before the time of the lease.

Under those conditions I think it is necessary to have a permit as well as the later granting of title, both in fee simple and on a leasehold. I say so because it is more favorable to the prospector. I think that with the government as the lessor it will work out better than with a lease from a private individual.

I have faith in the integrity and the sincerity of government officials, as ordinary American citizens. I will say further that I believe the oil men of California have as much confidence in government officials as they have in some of the landlords who have secured title from the government simply to impose hard conditions on the real oil men who operate under leases secured from oil men who are not producing oil men.

The Placer Law as Applied to Petroleum

BY MAX W. BALL,* WASHINGTON, D. C.

(New York Meeting, February, 1914)

AN intelligent discussion of the oil situation and its needs, whether from the standpoint of the prospector, the operator, the engineer, or the public administrative officer, must be founded upon a knowledge of the law under which oil lands are obtained. A consideration of new legislation must be prefaced by an understanding of the present law and its results. This paper undertakes to present no new remedy for the ills of the present situation, no new solution of the problems the oil business is facing. It attempts merely to summarize the present law, its provisions, its origin, its development, and its effects. The discussion does not pretend to be exhaustive from a legal standpoint. It aims to avoid legal intricacies which tend to confuse rather than clarify. It seeks but to present the essentials of the existing situation.

The title to government lands known to contain valuable deposits of petroleum may be acquired only under the terms of the placer law as embodied in Section 2329 *et seq.* of the Revised Statutes. As a preliminary to considering the desirability of this situation it is profitable to examine into its origin.

ORIGIN OF THE LAW

Congress has left no room for doubt as to the legal applicability of the placer law to oil lands. The Act of Feb. 11, 1897 (29 Stat., 526), provides:

"that any person authorized to enter lands under the mining laws of the United States may enter and obtain patent to land containing petroleum or other mineral oils, and chiefly valuable therefor, under the provisions of the laws relating to placer mineral claims."

The immediate cause for the passage of this Act was stated in a brief report in the House of Representatives (there was no debate in the Senate) to be a decision of the Department rendered Aug. 27, 1896 (Union Oil Co., 23 L. D., 223), directing the cancellation of an oil placer entry on the ground that land containing petroleum cannot be located and entered as a placer mine. The report of the Public Lands Committee of the House contains the following interesting statements (*Congressional Record*, vol. xxix, p. 1409):

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* Chairman Oil Board, U. S. Geological Survey. Non-member.

"The Committee on the Public Lands, having had under consideration House bill 9983, report the same back with the recommendation that it do pass.

"Public lands containing petroleum and other mineral oils have been held and patented under the placer mining acts of the United States for many years past. . .

"Under these rulings and in view of the uniform practice of the Land Department for many years, considerable quantities of lands have been filed upon, held, and improved for the purpose of developing oils in various of the public-land States, and in many instances large sums of money have been expended in such development.

"Under a decision of the Secretary of the Interior, dated August 27, 1896, in the case of mineral entry No. 140, Los Angeles district, California, the Secretary held that lands containing oils could not be patented under the placer-mining acts, for the reason that the acts did not originally contemplate the extension of their provisions to lands of this character. It has never been held by any authority that the provisions of the placer acts were not adequate to meet the conditions surrounding the development of mineral oils. The effect of the above-cited decision of August 27, 1896, is to preclude the possibility of obtaining title to lands containing oils, and as there are large areas of such lands in various of the public-land States, and as upon these lands in many instances large expenditures have already been made, and as it is manifestly for the public good that there should be some provision whereby these lands may be held and patented, the committee believe this bill should pass."

Secretary Hoke Smith, in the Union Oil Co. decision of Aug. 27, 1896, to which the committee refers, is by no means so convincing as is the report just quoted as to the previous practice of the Department. He states, with regard to the extension of the placer Act to cover petroleum (23 L. D., 228):

"But the subject has been, indirectly at least, before the Department several times, and while it has never been definitely decided, so far as I can ascertain, yet there seems to have grown up the idea that the rule prevails. An examination of the cases, however, will demonstrate the fact, I think, that there is no precedent for such belief."

After considering the various cases theretofore decided bearing more or less directly upon the question, he concludes:

"I am unable to agree that it falls within the contemplation of the mineral laws, and that it may be located and entered as a placer mine."

A reading of the cases cited by Secretary Smith shows that the specific question of whether or not petroleum-bearing lands are properly enterable under the placer Act was in no case definitely and squarely decided, although some of the cases, and particularly that of the Piru Oil Co. (16 L. D., 117), imply that such entry might with propriety be made. A letter by Secretary Bliss to the Commissioner of the Land Office under date of Nov. 6, 1897, reviewing the Union Coal Co. case (25 L. D., 351), explains this dearth of specific decisions on the point as follows (p. 354):

"From an examination of the records of your office, which I have caused to be made, it is ascertained that ever since the circular of July 15, 1873, until the date of the decision complained of, the practice of allowing entry and patent for lands chiefly valuable for their deposits of petroleum, under the law and regulations relating to placer claims, has been continuous and uniform. Under this practice a large number of patents have

been issued, and very large and valuable property interests have been acquired. Until the decision in this case, the correctness of the practice does not appear to have been questioned, and for that reason no case distinctly presenting such a question ever reached this Department."

It is interesting to note that as early as Mar. 17, 1865, the Commissioner of the General Land Office wrote, in response to an inquiry by the local land officers at Humboldt, Cal.:

"It is not the policy of the Government to deal with petroleum tracts as ordinary public lands, any more than with auriferous or other mineral or saline lands. Hence, you will report the exact description of any and all tracts strictly of the character you mention, and will withhold the same from disposal by the Government, unless otherwise specially instructed."

The history of the matter in reality begins with the discovery of gold in California in 1848. Prior to that time, and for many years thereafter, there was no law providing for the acquisition of title to mineral lands on the public domain, with the exception of special Acts providing for the sale of lands in the middle West valuable for ores of the baser metals. The development in California and adjacent parts of Nevada of a mining industry involving a large and heterogeneous population necessitated some code of rules to govern and guide the vast and intense mining activities. The Federal government failing to provide such a code, and there being no State or Territorial government, the miners of the various districts formulated and enforced, with greater or less definiteness and rigidity, local rules founded on the customs which had grown up by common consent in the interest of justice and fair play. These local regulations obviously could not provide for acquiring title from the United States, but they did prescribe the size of the claim, the method of locating and marking it, and the amount of assessment work necessary to hold it. The common underlying theory of these local rules in all the districts was that discovery of mineral is the one fundamental prerequisite to the establishment of a right or title. After the State of California was admitted to the Union both the legislature and Congress recognized the local codes as governing when not in conflict with the statutes or laws of the State. Recognition of the district rules was also accorded by the Federal courts and by the Land Department (Lindley on Mines, pp. 72 and 73, cases cited in footnotes).

It was not until July 26, 1866, that a Federal law was passed governing the mining industry of the public domain. This Act (14 Stat., 251) recognized and continued the local codes so far as not in conflict with the laws of the United States, and provided for the granting of title in fee to veins or lodes of quartz, or other rock in place, bearing gold, silver, cinnabar, or copper. Strangely enough, the Act of 1866 made no provision for the acquisition of title to placer claims, and to remedy this

omission Congress passed the so-called placer Act of July 9, 1870 (16 Stat., 217), amending the Act of 1866 by providing:

"That claims usually called 'placers' including all forms of deposit excepting veins of quartz, or other rock in place, shall be subject to entry and patent under this act, under like circumstances and conditions, and upon similar proceedings as are provided for vein or lode claims; . . . "

The lode law of 1866 was replaced by the general mining Act of May 10, 1872 (17 Stat., 91), which modified the procedure necessary to obtain patent to lode claims, emphasized the necessity of discovery as a prerequisite to location, and provided that the Act of July 9, 1870, should remain in force except as modified by the changes made in the lode law. Section 10 of the Act is in part as follows:

"That the act entitled 'An act to amend an act granting the right of way to ditch and canal owners over the public lands, and for other purposes,' approved July ninth, eighteen hundred and seventy, shall be and remain in full force, except as to the proceedings to obtain a patent, which shall be similar to the proceedings prescribed by Sections 6 and 7 of this act for obtaining patents to vein or lode claims."

The Acts of 1872 and of 1870 were incorporated into the Revised Statutes and are the mining law of the present day. Thus Section 2329 provides:

"Claims usually called 'placers,' including all forms of deposit, excepting veins of quartz, or other rock in place, shall be subject to entry and patent, under like circumstances and conditions, and upon similar proceedings, as are provided for vein or lode claims; but where the lands have been previously surveyed by the United States, the entry in its exterior limits shall conform to the legal subdivisions of the public land "

The language of this section and of the Act of 1870, from which it was taken, is sufficiently comprehensive to cover all the minerals known, or ever to become known, to man. There is, however, nothing in the debates in Congress to indicate that the sweeping words "all forms of deposit" were adopted with the intention of including minerals not then important but later to become so. The debates in both houses of Congress indicate that the placer Act was passed for the purpose of granting title to the gold-placer claims of the far West, and that the all-inclusive wording was adopted as the easiest way to distinguish these claims from so-called quartz claims. It was the result not of a far-sighted attempt to include other minerals which might later become of importance, but of a failure to foresee or to consider the possibility that such minerals might be discovered and be included within the all-embracing language. The speeches by Senator Stewart, of Nevada, who piloted the bill through the Senate, and by Mr. Sargent, of California, who introduced it in the House, embody the only reasons advanced on the floor of Congress for the passage of the Act, Senator Stewart thus stating its object (*Congressional Globe*, 41st Congress, 2d session, p. 3054, vol. xci):

"The act (of 1866) proposed to extend the principle of the preemption laws to quartz veins. I wish to say to the Senate that the act has been in operation now four years, and so far as quartz veins are concerned it has proved very beneficial. The purpose of this bill is to extend it to placer mines. There was a difficulty at that time in extending it to placer mines, so as to give homes to those who have worked at the diggings of the foothills of California and elsewhere where there were placer mines. They got no title, and they cannot prosper for that reason. They have got little orchards and little homes, and we want them to get title to their property. They have a placer mine where they can work a little in the winter, perhaps get a few dollars to keep along, and then they have a little orchard and they want one hundred and sixty acres of this land. Now, for the purpose of allowing them to get these homes the bill extends the principle of preemption to these worn-out placer diggings. That is the object of the bill."

The remarks of Mr. Sargent in the House are much more extensive than those of Senator Stewart in the Senate, and dwell at length upon the situation in the gold-placer districts in California, and to a less extent in Colorado. His discussion is confined to the gold placers, without reference to the possibility of other minerals, and this constant references to the manner and difficulty of finding placer gold and to the desirability of granting title to gold deposits only emphasize the completeness with which his mind was filled with the thought of this mineral, to the exclusion of all others. It is interesting to note that Mr. Sargent's principal argument is that the granting of title to placer claims would attach the migratory miner to the land, and would give a permanence similar to that of agricultural communities to the mining camps. His attitude is only feebly indicated by the following quotations from his speech of Mar. 18, 1870 (*Congressional Globe,* 41st Congress, 2d session, p. 2028, vol. xc):

"In July, 1866, Congress passed a law by which the holders of quartz mining claims could purchase their claims. It extended the principle of the preemption laws and recognized the possession of miners so far as quartz mines were concerned. . . . The proposition of this bill is to extend the principles of that act. . . . We propose by this bill to allow the placer miner who owns a limited quantity of land under mining customs to come before the land office and make proof of his possession, and having so done to the satisfaction of the Government, and shown that there is no adverse claim whatever, that then he shall pay double the minimum price for his claim and have a patent for it. . . .

". . . The effect of it will be that our mining population will be attached to the soil, that they will be changed from the nomadic, wandering character which they now have to settled communities."

Although Congress so evidently had in mind only gold placers, the Land Department seemingly had no hesitancy in applying the apparently comprehensive language to other minerals, among them being oil. On July 15, 1873, Commissioner Drummond of the General Land Office issued a circular in which he stated (Copp's *Mineral Lands,* p. 61):

"That whatever is recognized as a mineral by the standard authorities on the sub-

ject . . . should be treated by this office as coming within the purview of the mining act of May 10, 1872,"

and

"That lands valuable on account of borax, carbonated soda, nitrate of soda, sulphur, alum, and asphalt, as well as 'all valuable mineral deposits,' may be applied for and patented under the provisions of the mining act of May 10, 1872."

On Jan. 30, 1875, Commissioner Burdett, in response to a specific inquiry as to whether or not land yielding petroleum might be patented under the mining Acts, wrote (1 Copp's *Land Owner*, 179; Sickles *Mining Laws*, 491):

"Petroleum claims may be entered and patented under the mining act of May 10, 1872, upon full compliance with the provisions and requirements of said act."

According to the report of the House Public Lands Committee already quoted (*Congressional Record*, vol. xxix, p. 1409), the first patent to an oil claim was issued Mar. 22, 1880, for mineral entry No. 18, Los Angeles district, California. Further inquiries appear, however, to have been raised, for under date of Mar. 31, 1882, Commissioner McFarland expressed himself rather emphatically (9 Copp's *Land Owner*, 51):

"Lands containing deposits of petroleum have been entered as placers and patented as such. Your inquiries are fully answered, therefore, by stating that lands of that character are subject to entry and disposal according to the law and regulations relating to placer claims."

It will be noted that these rulings were all by the Land Office and were, therefore, subject to review by the Secretary of the Interior. Although the Department must have acquiesced in the matter, there appears to be, as already pointed out, no case in which the Secretary passed squarely upon the question until the adverse decision of Aug. 27, 1896, which resulted in the Act of Feb. 11, 1897, definitely extending the placer law to oil lands.

Provisions of the Law

Having thus examined into the origin of the placer law and its application to petroleum, the reasons for its various provisions become apparent.

The most important requirement is that a discovery of mineral must be made before possessory rights attach. This principle, which, as we have already seen, was fundamental in the miners' codes, was adopted into those codes from the Spanish and Mexican law. Section 2329 of the Revised Statutes provides for placer claims "under like circumstances and conditions and upon similar proceedings" to those for lode claims. Section 2320 provides that "no location of a mining claim shall be made until the discovery of a vein or lode within the limits of the claim located."

Lindley summarizes the law on the subject as follows (Lindley on Mines, pp. 779 and 781):

"Discovery is just as essential in case of placers as it is in lode locations. The supreme court of California at one time expressed the view that neither the federal laws nor the local rules and customs of miners required that a discovery should be made as a prerequisite to a placer location, but this is obviously a mere dictum; it is also opposed to the current of judicial authority. The land department has uniformly held that discovery is essential in the case of placers, going so far at one time as to hold that such discovery was essential in each twenty-acre tract within a location of one hundred and sixty acres located by an association of persons.

"In the case of petroleum deposits the courts in California have in recent years been confronted with some serious problems upon the subject of what constitutes a sufficient discovery which will sanction a location of a claim to oil lands under the laws applicable to placers. It is well known that the natural habitat of this class of mineral hydrocarbons is in stratified rocks some distance below the surface, and except for the occasional appearance at the surface in the form of oil seepages, springs, or other indications of the subterranean existence of petroleum, there is nothing to guide the miner in making his location. It requires more or less extensive development in the nature of well boring and prospecting to determine the nature, extent, and permanency of the deposit.

"Of course, exploitation on adjacent lands might raise a strong presumption that a given tract contained petroleum. An oil-producing well within each of four sections of land surrounding a fifth would produce a conviction that the oil deposit was underneath the fifth section. This fact might justify the land department in classifying the section in the category of mineral lands, or the government surveyor in returning it as such, but it would not dispense with the necessity of making a discovery."

The only essential to a valid location in addition to a discovery of mineral is, so far as the Federal law is concerned, that the claim be "distinctly marked on the ground so that its boundaries can be readily traced" (R. S. 2324). In many instances State laws and local regulations prescribe other requirements, such as posting a location notice on the claim and the recording of the location with a specified district or county officer. Once these requirements have been met the locator has "the exclusive right of possession and enjoyment of all the surface included within the lines" of his claim (R. S. 2322). The claim may comprise 20 acres if located by an individual or, if made by an association, 20 acres for each member thereof (R. S. 2321), but in no case may it exceed 160 acres (R. S. 2320). There is no limit upon the number of claims which may be located by a single individual or association.

Having complied with all the requirements necessary to a valid location and having thus become entitled to exclusive right of possession, the claimant, in order to continue the right, must expend not less than $100 worth of labor or improvements upon the claim during each year (R. S. 2324). The requirement of development work as a condition of continued possession of mining property was, like the discovery requirement, incorporated into the local regulations from the mining laws of Spain and Mexico. Failure to perform the required assessment work forfeits the right to exclusive possession and the claim becomes "open to relocation in the same manner as if no location . . . had ever been

made" (R. S. 2324). The present law gives the claimant until the end of the calendar year succeeding his location in which to perform his first assessment work (21 Stat., 61), and thereafter the calendar year is the period for which such work is required.

If the claimant has made a valid discovery and has expended not less than $500 worth of labor or improvements upon the claim (R. S. 2325), he is, upon compliance with certain requirements as to posting notices, publication, survey (R. S. 2325), and upon payment of $2.50 an acre (R. S. 2333), entitled to a patent conveying a title in fee to the area covered by his claim. The right to patent may also be earned by holding and working a placer claim for the period prescribed by the statute of limitations of the State in which the claim is situated (R. S. 2332), but this right is rather infrequently exercised, is not of especial importance to the present discussion, and will not hereinafter be considered.

It is evident that there are three stages of development of the title which a claimant under the placer law acquires to the land included within his claim: First, the period between his physical occupation of the claim and his making location; second, the period between his location and patent; and third, the period after patent.

The third case requires no discussion. The patent is a grant of title in fee simple, good against the grantor and all adverse claimants, and subject to attack only upon the ground of fraud.

The character of title during the period between location and patent, while by no means clearly or consistently defined by the courts, is nevertheless such as to protect the claimant in the exclusive possession and enjoyment of his claim so long as he performs his annual assessment work and complies with State and local regulations. Lindley in reviewing the character of this estate says (Lindley on Mines, p. 892):

> "Prior to the issuance of a patent the locator cannot be said to own the fee-simple title. The fee resides in the general government, whose tribunals, specially charged with the ultimate conveyance of the title, must pass upon the qualifications of the locator and his compliance with the law. Yet, as between the locator and every one else save the paramount proprietor, the estate acquired by a perfected mining location possesses all the attributes of a title in fee, and so long as the requirements of the law with reference to continued development are satisfied, the character of the tenure remains that of a fee. As between the locator and the government, the former is the owner of the beneficial estate, and the latter holds the fee in trust, to be conveyed to such beneficial owner upon his application in that behalf and in compliance with the terms prescribed by the paramount proprietor."

It should be borne clearly in mind and cannot be too strongly emphasized that this character of right and title is present *only after location* and that *no location can be made unless founded upon discovery.* Unless he has made discovery no amount of development work and no compliance with other Federal, State, or local requirements (except that

of possession and work for the period prescribed by the statute of limitations; R. S. 2332) will confer upon the claimant an equitable title as against the government or a tenure in the nature of a fee against others. As against the government, the mineral claimant who has made no discovery has in fact no title whatever, either legal or equitable. Neither has he any vestige of title against strangers so far as the Federal laws are concerned. He is not before the Department until he has made discovery of mineral on which to found a location. Consequently the Department cannot, even if it would, protect him against intruders upon his occupancy or violators of his possession. He has, however, been granted some measure of protection, none too clearly defined, by the courts, and the measure of this protection is a matter of great concern to the prospector for deep-seated deposits. How far will the courts safeguard his occupancy and possession prior to discovery against, first, agricultural claimants, and second, other mineral claimants?

The leading case upon the rights of a mineral occupant against an agricultural claimant is Cosmos Exploration Co. vs. Grey Eagle Oil Co. (112 Fed., 4). In this case, which was affirmed by the Supreme Court of the United States, although this point was not specifically mentioned (190 U. S., 310), it is stated that the defendants had made "pretended placer mining locations" upon the land in controversy but had made no discovery, that thereafter complainant selected this land in lieu of certain lands in the national forest under the Act of June 4, 1897 (36 Stat., 11, 36), which provides for the selection of "vacant land open to settlement," and that subsequently defendants discovered oil in paying quantities. The Circuit Court of Appeals of the ninth circuit held (syllabus):

"Land was not 'vacant and open to settlement,' and subject to selection under such act, where at the time of the application it was in the actual occupancy of others engaged in exploring it for oil, under oil placer mining locations previously made by them, although such locations did not appear by the records of the local land office, and although they were not valid as against the United States, because there had been no previous discovery of oil on the land, where the locators prosecuted the work of exploration with due diligence, and with the result of discovering oil in paying quantities before the selection by the applicant under the forest reserve act had been approved by the land department. Until by such approval an applicant is vested with the equitable title to the land, it remains subject to exploration for minerals under the mining laws; and, while lawfully occupied by one engaged in making such exploration, it is not 'vacant' within the meaning of the act; nor is it open to settlement where, as the result of such exploration, its mineral character is established, while the title, both legal and equitable, remains in the United States."

It should, however, be noted that while under this decision the prospector proceeding in good faith to explore for minerals is protected against adverse agricultural claimants, there is nothing of record in the Land Office to show that the land which he occupies is not "vacant and

open to settlement," and such agricultural filings are likely to be made at any time, subjecting him to the expense of maintaining contest proceedings before the Land Department or the courts. It may also be worthy of note that some importance seems to be attached to the fact that oil was discovered before the agricultural selection had been approved.

That a measure of protection is afforded against adverse mineral claimants who attempt by forcible, fraudulent, or surreptitious means to violate the possession of a mineral occupant proceeding in good faith, is held by Miller vs. Chrisman (140 Calif., 440), in which Mr. Justice Henshaw says:

"It is to be remembered that it is not essential to the validity of a location that the discovery shall have proceeded or shall coexist with the posting of the notice and the demarcation of boundaries. The discovery may be made subsequently, and when made operates to perfect the location against all the world, saving those whose bona fide rights have intervened. One who thus in good faith makes his location, remains in possession, and with due diligence prosecutes his work toward a discovery, is fully protected against all forms of forcible, fraudulent, surreptitious, or clandestine entries and intrusions upon his possession. Such entry must always be peaceable, open and above board, and made in good faith, or no right can be founded upon it. (Belk vs. Meagher, 104 U. S., 279; Atherton vs. Fowler, 96 U. S., 513; Nevada Sierra Oil Co. vs. Home Oil Co., 98 Fed., 673.)"

And further:

"It further appears that certain valuable rights become the property of such locators even before discovery. They have the right of possession against all intruders (Garthe vs. Hart, 73 Cal., 541), and they may defend this possession in the courts. (Richardson vs. McNulty, 24 Cal., 339.) They have then this right of possession and with it the right to protect their possession against all illegal intrusions, and to work the land for the valuable minerals it is thought to contain. We cannot perceive why these rights may not in good faith be made the subject of conveyance by the associates as well before as after discovery."

Although it would thus appear that a mineral claimant prior to discovery may not be ousted from his possession by force or fraud, it has been held repeatedly that his possession is not good against that of an adverse claimant who enters upon the land in good faith and in compliance with the law and proceeds to make a discovery. The quotations from Miller vs. Chrisman just given confirm this by implication and cite among others the case of Garthe vs. Hart (73 Cal., 541). In this case the court below has instructed the jury as follows:

"As I said, there is still another way by which a miner in this state may acquire a right to the possession of a piece of mining ground. It is by taking possession of it and clearly defining the boundaries so that they may be readily traced, and holding such possession, keeping such possession."

The appellate court reversed the lower court on this and other grounds, saying *inter alia:*

"In the hurry of the trial, the learned judge evidently overlooked the distinction between the right of a party in possession as against mere intruders, and his right as against one who has complied with the mining laws. Possession is good against mere intruders (Attwood v. Fricot, 17 Cal. 37; S.C., 76 Am. Sec. 567; English v. Johnson, 17 Cal. 115; S.C., 76 Am. Dec. 574; Hess v. Winder, 30 Cal. 355; Golden Fleece Co. v. Cable Con. Co., 12 Nev. 321, 322); but it is not good as against one who has complied with the mining laws. (Du Prat v. James, 65 Cal. 556, 557.)"

In Miller vs. Chrisman, *supra*, the Supreme Court also cited the leading case of Belk vs. Meagher (104 U. S., 279). In this case, which is not as clear or simple as might be wished, the facts were stated to be as follows (syllabus):

"A. entered Dec. 19, 1876, upon a claim not then in the actual possession of any one, but covered by a valid and subsisting location which did not expire until the first day of January thereafter. Between the date of his entry and Feb. 21, 1877, he made no improvements or enclosure, and did a very small amount of work, but had no other title than such as arose from his attempted location of the claim and his occasional labor upon it. On the last-mentioned date B. entered upon the property peaceably and in good faith, and did all that was required to protect his right to the exclusive possession thereof. A. brought ejectment October 25, 1877. *Held*, that A's entry and labor did not entitle him to a patent under sect. 2332, Rev. Stat., nor prevent B's acquisition of title to the claim. . . ."

The court through Mr. Chief Justice Waite said:

"No one contends that the defendants affected their entry and secured their relocation by force. They knew what Belk had done and what he was doing. He had no right to the possession, and was only on the land at intervals. There was no enclosure, and he had made no improvements. He apparently exercised no other acts of ownership, after January 1, than every explorer of the mineral land of the United States does when he goes on them and uses his pick to search for and examine lodes and veins. As his attempted relocation was invalid, his rights were no more than those of a simple explorer. In two months he had done, as he himself says, 'no hard work on the claim,' and he 'probably put two days' work on the ground.' This was the extent of his possession. He was not an original discoverer, but he sought to avail himself of what others had found. Relying on what he had done in December, he did not do what was necessary to affect a valid relocation after January 1. His possession might have been such as would have enabled him to bring an action of trespass against one who entered without any color of right, but it was not enough, as we think, to prevent an entry peaceably and in good faith for the purpose of securing a right under the act of Congress to the exclusive possession and enjoyment of the property. The defendants having got into possession and perfected a relocation, have secured the better right."

The court also said:

"His ultimate right to a patent depended entirely on his keeping himself in and all others out, and if he was not actually in, he was in law out. A peaceable adverse entry, coupled with the right to hold the possession which was thereby acquired, operated as an ouster. . . . He had made no such location as prevented the lands from being in law vacant. Others had the right to enter for the purpose of taking them up, if it could be done peaceably and without force. There is nothing in Atherton v. Fowler (96 U. S., 513) to the contrary of this. . . ."

This doctrine has been followed in many cases (Lindley on Mines, p. 375, cited in footnote No. 2). In Thallman vs. Thomas (111 Fed., 277), the Circuit Court of Appeals for the eighth circuit said (Lindley on Mines, p. 376):

"Every competent locator has the right to initiate a lawful claim to unappropriated public land by a peaceable adverse entry upon it while it is in the possession of those who have no superior right to acquire the title or to hold the possession. . . . Any other rule would make the wrongful occupation of the public land by a trespasser superior in right to a lawful entry of it under the acts of Congress by a competent locator."

In Crossman vs. Pendery (8 Fed., 693), it was held (Lindley on Mines, pp. 370 and 371):

"A prospector on the public mineral domain may protect himself in the possession of his *pedis possessionis* while he is searching for mineral. His possession so held is good as a possessory title against all the world, except the government of the United States. But if he stands by and allows others to enter upon his claim and first discover mineral in rock in place, the law gives such first discoverer a title to the mineral so first discovered, against which the mere possession of the surface cannot prevail."

Lindley summarizes the law of the matter as follows (Lindley on Mines, pp. 378 and 379):

"(1) Actual possession of a tract of public mineral land is valid as against a mere intruder, or one having no higher or better right than the prior occupant;

"(2) No mining right or title can be initiated by a violent or forcible invasion of another's actual occupancy;

"(3) If a party goes upon the mineral land of the United States and either establishes a settlement or works thereon without complying with the requirements of the mining laws, and relies exclusively upon his possession or work, a second party who locates peaceably a mining claim covering any portion of the same ground, and in all respects complies with the requirements of the mining laws, is entitled to the possession of such mineral ground to the extent of his location as against the prior occupant, who is, from the time said second party has perfected his location and complied with the law, a trespasser."

The principal question which this leaves unsettled is, what means may a prior occupant take and to what extent may he go in preventing the peacable and open entry which will, if it ripen into a valid location, dispossess him. The answer to this question does not appear to be found in the court decisions nor does the forcible prevention of entry, in some cases by the threatened or actual use of fire-arms, seem a satisfactory answer.

Application to Petroleum Lands

What are the effects of these various provisions, statutory and judicial, upon the development of deposits of petroleum on the public domain? Is the placer law as thus interpreted best from the standpoint of the oil prospector and oil operator, and is it wisest from the stand-

point of the government? What is the net result of applying a law designed for stable, stationary minerals occurring in easily accessible deposits to a fluid mineral occurring at great depth below the surface and requiring long-continued and expensive development work to discover? In discussing these questions, frequent reference will be made to the hearings held May 13 and 17, 1910, before the Committee on the Public Lands of the House of Representatives, upon H. R. 24070, "A bill to authorize the President of the United States to make withdrawals of public lands in certain cases." The record of these hearings will hereinafter be referred to as "H. R. 24070."

Inadequate Protection Prior to Discovery

The first weakness which presents itself when the placer law is applied to petroleum is the inadequate protection afforded prior to discovery. Oil in large quantities is seldom, if ever, found in nature on the surface of the ground. The natural laws under which it accumulates require a superincumbent rock covering of considerable thickness and density. With the exception of negligible quantities gathered from seepages and springs, all the oil produced in the United States comes from wells of greater or less depth, and it is only by means of such wells that discovery can be made. In Miller vs. Chrisman (140 Calif., 440) the court says on this subject:

"To constitute a discovery, the law requires something more than conjecture, hope or even indications. The geological formation of the country may be such as scientific research and practical experience have shown to be likely to yield oil in paying quantities. Taken with this, there may be other surface indications, such as seepage of oil. All these things combined may be sufficient to justify the expectation and hope that, upon driving a well to sufficient depth, oil may be discovered, but one and all they do not in and of themselves amount to a discovery. This view finds support in the Nevada Sierra Oil Co. vs. Home Oil Co., 98 Fed. 673, where the circuit court was dealing with this precise question, in regard to this precise piece of land, under these identical circumstances. While perhaps it would be stating it too broadly to say that no case can be imagined where a surface discovery may be made of oil sufficient to fill the requirements of the statute, yet it is certainly true that no such case has ever been presented to our attention, and that in the nature of things such a case will seldom, if ever, occur."

Thomas A. O'Donnell, of Los Angeles, was introduced to the Public Lands Committee of the House of Representatives as "one of the oldest operators in the field—that is, not in point of years but in point of experience. He is one of our pioneers there, and is thoroughly familiar with all the facts." Mr. O'Donnell said (H. R. 24070, p. 5):

"The placer miner, looking for gold, could go along with a shovel and turn over a little gravel and get a color of gold, and he had then made the necessary discovery. But our petroleum in California is in many instances 4,000 ft. under the earth, and it is being developed successfully to-day from that depth.

"You gentlemen can readily see the absolute necessity for the oil miner to go upon this land and proceed to make that discovery. In many instances, gentlemen, with the difficulties that have arisen in this development it has taken years to find out whether a piece of land was really oil land or not and to make the discovery which is necessary before you can make application to the Land Department and acquire title to the land.

"In the case of nine-tenths of the government land in California on which men are operating to-day there is absolutely no record in the Land Office of their operations. We cannot get near the Land Office until we have made a discovery.

These discovery wells not only require long periods, some of them months or even years, to drill, but they cost large sums of money. It has been estimated that the average cost of each successful well in the State of California within the last year or two has exceeded $15,000. It is no uncommon thing for a well to cost over $50,000. Thus the oil operator must expend large sums of money during the months required to make a discovery, and until such discovery is made he may be dispossessed and his expenditure lost if another operator enters upon the land (by other than forcible, fraudulent, or surreptitious means) and makes prior discovery. The following colloquy between Hon. Sylvester C. Smith, Representative from California, and A. I. Weil, of San Francisco, before the Public Lands Committee of the House illustrates the situation (H. R. 24070, pp. 7, 8):

"Mr. Smith: I think, however, you will admit that this is the state of affairs in California: If A goes on a quarter section, having monumented the corners as a mining claim, and begins to drill, and B comes onto the same quarter section and wants to begin to drill, the courts will not put B off.

"Mr. Weil: Oh, no; they will not put him off.

"Mr. Smith: He has the right to go on and begin to drill side by side with A.

"The Chairman: Yes, but what will the court say to B if B makes the discovery first?

"Mr. Weil: That has not been decided.

"Mr. Smith: My opinion is that they are bound to hold in his favor.

"The Chairman: That is my curbstone opinion.

"Mr. Smith: Because he is the man who first unites a discovery with a location.

* * * * * * * * * *

"Mr. Smith: But the difficulty is this: A person makes a location. He has no security whatever in his tenure.

"The Chairman: Unless he works.

"Mr. Smith: Even if he works he has not, because B may come and sit down beside him and commence drilling. Therefore A, who makes the first location, cannot go out and enlist capital, or does not always feel like bringing his own capital into the enterprise, fearing that B may come along and beat him to the oil.

"The law ought to be such that when a man in some proper manner obtains possession of a piece of government land for a purpose he can hold it against the world until he has worked out his purpose. It is not so under this situation. A man may go in there with ever so good faith and stake out a quarter section and put on his rig and begin to drill; and yet another man or 20 men can come on the same land and sit down beside him and begin to drill, too."

That such large amounts have been and are being invested in oil prospecting with no greater security of title than the placer law affords would seem to be due solely to the large percentage which the investment returns if it is successful. Certainly the law, even under the most favorable court interpretations, affords meager protection for such sums, and permits interference with and annoyance of the legitimate prospector which amount to little short of blackmail. Mr. O'Donnell, already quoted, refers to some of the more common practices. On p. 7 of the record he says (H. R. 24070, p. 7):

"It is sometimes very hard to tell exactly where your lines are; and it has been quite a trick on the part of some unscrupulous persons to erect a derrick on their own property and slip it across the line."

And on p. 10 (H. R. 24070, p. 10):

"In many instances in the little towns on midnight of January 1, almost all of the saloon men, and the men that spend a great deal of their time in these towns, go out and locate the whole country. Then they come and ask for a bonus from the operator, from me, from the driller that tries to organize a little company among his associates and go out to drill on that land."

Since it is clear that the oil prospector is subject to the loss of his possession if an adverse claimant makes peaceable and open entry in good faith and discovers oil, it is to his interest to prevent such peaceable and open entry. The extent to which such entry is prevented and the means taken thereto seem to vary with the field. As stated by Mr. O'Donnell with regard to California operators (H. R. 24070, p. 9) "when they were in legitimate pursuit of discovery they were seldom disturbed." Nevertheless instances are not wanting where gunmen have been hired to prevent attempts to enter and occupy lands already being prospected. Neither is it uncommon to see dozens of location notices put up by different locators on the same claim, each in the hope that his location will be validated by a discovery or that the courts will accord him priority of possession. Such conditions inevitably tend to violence or litigation or both.

In some of the fields, particularly in the Rocky Mountain States, almost any kind of pretended development work appears sufficient to hold a claim for an indefinite period. Here many subterfuges have been adopted by those who wish to hold possession of valuable petroleum lands without the expenditure of the large sums necessary to make discovery. Rigs capable of drilling only to a few hundred feet have been erected for the purpose of doing assessment work on lands beneath which the oil sands were known to lie at depths of thousands of feet. Tunnels have been dug in hillsides to tap oil springs or seeps in the attempt to obtain inexpensively enough oil to constitute a discovery. In at least one Western State large areas have been claimed for years under assess-

ment work in the shape of roads, some of which make transportation to the fields easier, and some of which have only the merit of entailing the expenditure of the required amount of money. One large area is being held under building-stone placer claims, although much of the area is covered by dune sand and no building stone of especial value is known in the region. In some of the fields there are deposits of gypsum of fair quality upon the surface of oil lands of great prospective value. Many attempts have been made to obtain title to these lands by locating and perfecting gypsum placers. The West Side fields of the San Joaquin valley, California, are ornamented in places by Italian gardens carved in the gypsum by humorous assessment workers, and by graceful stairways which, as has aptly been said, lead nowhere but to a title to valuable oil lands.

A consideration of these various attempts, more or less successful, to hold oil lands without making or attempting to make discovery, and the instances of entry upon oil lands already being prospected for the purpose of making discovery in advance of the prior locator, would lead to the conclusion that in neither situation is the placer law satisfactory. If occupancy without discovery is respected, large areas are withheld from exploration and development, in some instances by a single individual or group of individuals. If, on the other hand, such occupancy is not respected, the oil prospector must assume undue risk of the loss of his investment prior to discovery.

Draining of Oil from Adjacent Lands

However, this is by no means the only objection, and in reality is not the greatest objection, to the placer law as applied to petroleum. Oil is a fluid which occurs saturating relatively porous beds beneath the earth's surface. Like any other liquid, it is subject to the laws of gravity, hydrostatic pressure, and capillarity, and it is in nearly every instance under greater or less gas pressure. When a well taps an oil sand and the oil immediately around the well is drawn off other oil from greater distances flows in and is also drawn off. The amount of oil under a given tract of land is thus not a constant, as would be the amount of some solid mineral. It is subject to change through the opening of wells on adjoining tracts, or through the flooding of the oil sands with water from mishandled wells. It is illogical to dispose of oil by the acre, for the very apparent reason that it may not stay under a given acre but may be drawn off by wells on neighboring acres. It is so well established in the law of real properly as to need no discussion that fluid substances are the property of the person upon whose lands they are brought to the surface, regardless of whose lands they originally underlay. When oil or gas "escape and go into other land, or come under another's control, the title of the former

owner is gone. If an adjoining owner drills his own land and taps a deposit of oil or gas, extending under his neighbor's field, so that it comes into his well, it becomes his property." (Brown vs. Spilman, 155 U. S., 665, 670, citing Brown vs. Vandergrift, 80 Penn. St., 142, 147; Westmoreland Nat. Gas Co.'s Appeal, 25 Weekly Notes of Cases (Penn.), 103.)

Since oil thus belongs to the producer thereof, it becomes advantageous for the owner of a given tract to so drill his wells that they will draw the maximum quantity of oil from adjacent lands. The radius which will be drained by a given well is not definitely known and is, of course, variable. Enough data are at hand, however, to show that considerable distances may be affected. W. W. Orcutt, of Los Angeles, in charge of the geological department of the Union Oil Co., testified before the Public Lands Committee (H. R. 24070, pp. 48, 50):

"Sometimes they will reach 1,000 feet; sometimes 2,000 feet, so that it is possible to take all, or nearly all, of the oil off of a very large area of land from one well. Usually the man who has the first well down in an area will get the bulk of the oil, because after the first well is drilled the gas pressure is loosened up, and it is all coming in that direction. The line of least resistance is toward the first well, and a well drilled subsequent to the first well will not get very much oil.

"I think a gentleman this morning made the statement that some wells he was interested in had produced 400 per cent. more than some wells his neighbor had drilled just across the line subsequent to the time he drilled his wells. That is a well-known fact. The man who gets the first well down in an area will get the bulk of the oil.

* * * * * * * *

"I have an instance in mind in the Santa Maria field, where practically all of the oil has been taken off of 80 acres from one well. That was a very strong well. It had a big gas pressure. When other wells were drilled on that 80-acre piece they got only little 'strippers' that did not amount to much."

Such information as has been obtained since the date of Mr. Orcutt's statement (1910) indicates that the instances are rare where a well drains a territory so large as that given in his statement. But the following statement by Mr. O'Donnell is significant (H. R. 24070, p. 14):

"The reason for putting them close together in the richer parts of the field is principally to get them along the line. If you will note, you will see that the closest driving is usually along the line, in order to get as much of the other fellow's oil as you can. In many instances we have drilling arrangements, spacing them, and making blue prints of each piece where we have an agreement, showing just how far a fellow shall put his well from his other well. That shows that the other fellow believes that if your wells are thicker on your particular piece of land they will affect his lands in time, even although they are half a mile away. After the discoveries are made, of course the industry is very profitable; and the development will proceed in the nature of a race, perhaps, along the line."

At any rate, the distances affected are known to be such that the practice of drilling as close as may be to the property lines is almost universal. The owner of tract A attempts to draw off the oil from his neighbor's

tract B and to forestall the neighbor in his attempt to drain the oil from tract A. Thus it becomes a race for the oil along the boundaries and each operator is forced to drill by the drilling of his neighbor. Whether or not he desires to drill, even although he is unable to dispose of more oil than he is already producing, or even if for financial or other reasons it would be to his advantage to defer the bringing in of new wells, the operator must nevertheless drill and operate wells along his boundaries or his neighbors will enrich themselves at his expense. Numerous statements by oil operators might be quoted showing the universality of the practice of line drilling and the necessity for it under the placer law, but an examination of the well map of any of the high-production public-land fields will show the present situation more conclusively than any statement. It is common practice to adopt so-called gentlemen's agreements as to the spacing of wells on neighboring areas, and by this means to attempt to prevent line racing and forced production. But while these agreements are in many instances advantageous they by no means solve the whole problem. Mr. O'Donnell says (H. R. 24070, p. 117):

"The general custom in the field is to have an agreement between adjoining operators to drill not nearer than 150 ft. from the line; and after you get your agreement, the custom is to drill your well at 150 ft. just as quick as you can."

It is noteworthy that the Office of Indian Affairs, in regulating oil and gas operations on Indian lands, has recognized the evils of line drilling. Many, if not all, of the oil leases stipulate that no well shall be drilled within 200 ft. of a division line unless necessary to offset wells on adjoining tracts. The following provisions seem to be typical (Regulations of Apr. 20, 1908, revised to May 1, 1912, governing leasing of lands of the Five Civilized Tribes):

"The lessee may be required to drill and operate wells to offset paying wells on adjoining tracts and within 300 feet of the dividing line.

"Lessees shall not be allowed to drill within 200 feet of the division lines between lands covered by their leases and adjoining lands, except in cases where wells on adjoining tracts are drilled at a less distance, in which case lessees may offset such wells by drilling at an equal distance from the line."

Forced Production

A third serious objection to the placer law, growing out of the two already discussed, is the economic loss through overproduction. The operator who has not made actual discovery of oil is insecure in his title. Furthermore, his neighbors may resort to line drilling and rob him of deposits of great value. He is forced, therefore, in fields where the competition is keen, to drill for and produce oil whether he has a profitable market or not. The result of this condition is seen in California, where,

in spite of a producer's association which tends to prevent the price of oil from falling so low as to ruin the industry, the oil stock on hand at the end of 1911 was over half the production of the State for that year. Thus is created a situation which is of great disadvantage to the producer of oil and of almost equal disadvantage to the public, since a large part of the surplus production is stored in open reservoirs where tests have shown that in some cases the volatilization loss is as great as 50 per cent. in five months. This loss is of the most valuable part of the oil and represents a tremendous and irredeemable waste.

Conclusion

It must be concluded that the placer law as applied to petroleum is unsatisfactory from almost every angle. It fails to adequately protect the prospector during the long and expensive exploration period. It permits in some cases the holding of a country side without real development or prospecting. It permits the extraction of oil from the territory of another and fosters and necessitates line drilling. It forces production in advance of demand and results in serious waste of a valuable resource. It alienates the fee from the government and endangers and renders difficult future government control.

It is not the purpose of the present discussion to endeavor to suggest new legislation. The objections to the placer law, however, force certain features of a satisfactory law upon the attention. The prospector should be given the exclusive right of possession of a restricted area for a limited period sufficient to prove or disprove its oil-bearing character. Thus the heavy investment required for oil exploration would be protected from loss by adverse claim. The operator should pay for his oil as a commodity in terms of barrels instead of as real property in terms of acres. If oil is the property of the producer thereof, the producer should pay for it, not the owner of the property from which it is drawn. The oil only should be sold and the title to the land should be retained in the government.

Addendum

It might be well to add to this discussion a brief statement of the effect upon the *bona fide* oil operator of withdrawals under the act of June 25, 1910 (36 Stat., 847). This act provides:

> "That the President may, at any time in his discretion temporarily withdraw from settlement, location, sale, or entry any of the public lands of the United States including the District of Alaska and reserve the same for water-power sites, irrigation, classification of lands, or other public purposes to be specified in the orders of withdrawals, and such withdrawals or reservations shall remain in force until revoked by him or by an act of Congress.

"*Provided*, That the rights of any person who, at the date of any order of withdrawal heretofore or hereafter made, is a *bona fide* occupant or claimant of oil or gas bearing lands, and who, at such date, is in diligent prosecution of work leading to the discovery of oil or gas, shall not be affected or impaired by such order so long as such occupant or claimant shall continue in diligent prosecution of said work."

The operator who has made a valid location supported by a discovery is of course not affected by a withdrawal under this Act. Neither is the operator who, although he has not as yet made discovery, is nevertheless engaged in the diligent prosecution of work leading thereto. A withdrawal therefore operates only against those claimants who are not diligently seeking a discovery. The effect of the withdrawal is to prevent the initiation of new rights upon the lands withdrawn by those not prosecuting work at the date of withdrawal. What is the net effect then upon the operator who was diligently at work at the withdrawal date, and who has continued diligently at work, but has not as yet made discovery? If there were no withdrawals it is entirely within the bounds of possibility, as already pointed out, for an adverse claimant to enter upon the land (if such entry be not forcible, fraudulent, or clandestine), drill upon it, and by first discovering oil, to obtain title to it. With a withdrawal order covering the land no such intrusion is possible. No new rights can attach subsequent to the withdrawal, and the operator who in good faith was diligently prosecuting work leading to discovery and who has continued to do so is protected by the withdrawal against all possibility of the initiation of adverse claims.

Is It Feasible to Make Common Carriers of Natural Gas Transmission Lines?

BY SAMUEL S. WYER, COLUMBUS, OHIO

(New York Meeting, February, 1914)

OVER 8,000,000 people in the United States depend on natural gas for their cooking, heating and lighting service. This service has been made possible only by the investment of large amounts of capital in transportation lines connecting the gas wells to the various communities, thus combining a *hazardous* mining operation with a public utility service. The effect that making these lines "common carriers" will have on the present and future service to these 8,000,000 or more people is of far reaching ethical and economic importance, and deserves careful consideration. As an introduction, it must be conceded that:

1. Natural gas, although a mineral and obtained by a mining operation—with more uncontrollable and uncertain features to cope with than exist in the mining of coal or other minerals—when served to the public becomes a public utility service.

2. The governmental power to regulate all public utilities in the interests of the public cannot be successfully disputed.

3. Mere suggestion of inconvenience to the utility is wholly irrelevant, as it cannot be considered or allowed to influence in making a defense against governmental regulation. Unfortunately it is not generally appreciated that:

1. Legislative enactments are not necessarily laws, and cannot abrogate economic laws or alter engineering facts.

2. There is a clear distinction between "common carrier" and "public utility," although the terms are frequently confused. "A common carrier is one who undertakes for hire to transport persons or goods, or both, from place to place for all persons indifferently, the term implying indifference as to whom shall be served, and an equal readiness to serve all who apply, in the order of their application."

On the other hand, property becomes a "public utility" only "when for a particular purpose the public have a right to resort to the premises and make use of them."

It is, therefore, important to note that not all public utilities can be regarded as common carriers. The U. S. Supreme Court has already

made this distinction in the case of telegraph lines, noting the peculiar service characteristics that prevail there. A proper analysis of natural

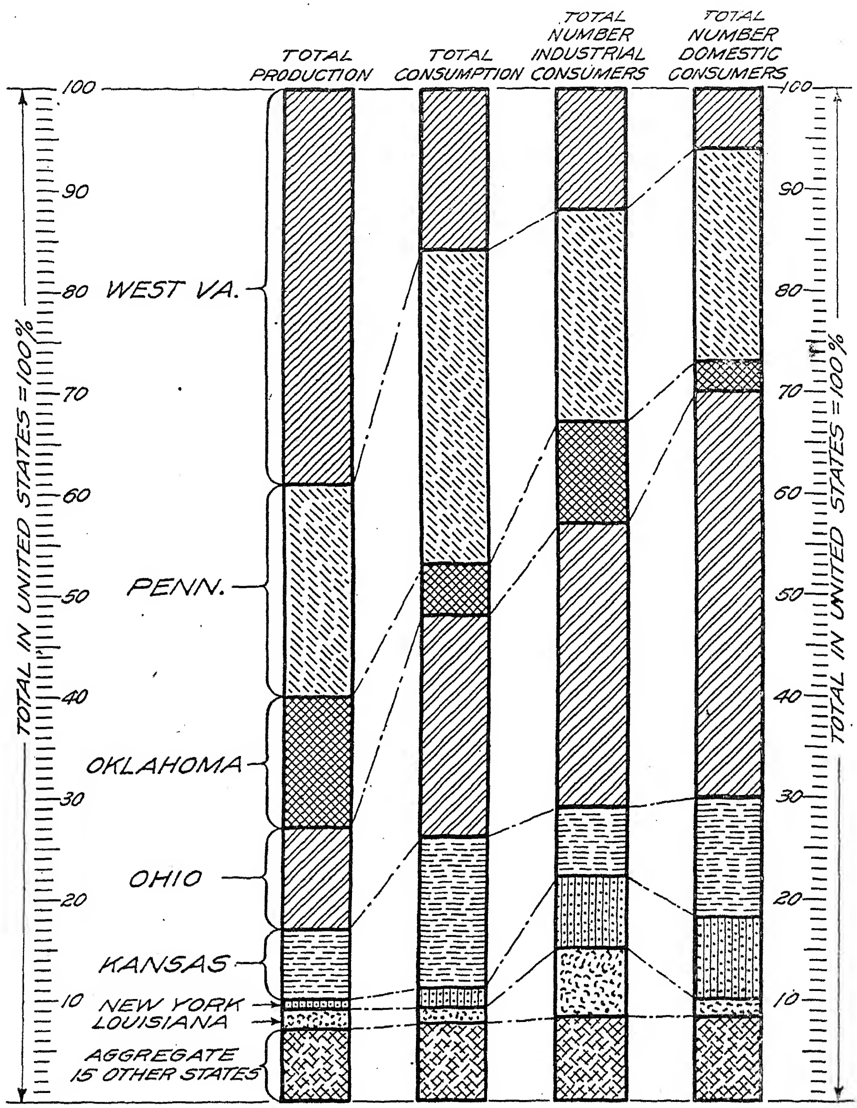


Fig. 1.—Interstate Relation of Production and Consumption of Natural Gas in the United States.

gas operating conditions will show that a similar exception ought to be made in the case of natural gas service.

3. Natural gas companies are not chartered to act and do not offer to act as common carriers.

4. The legal definition of "common carrier" cannot be applied to the natural gas business, for the reason that the fundamental requirement of the common carrier is non-discrimination. A gas company operating a natural gas transmission line and supplying domestic consumers, from

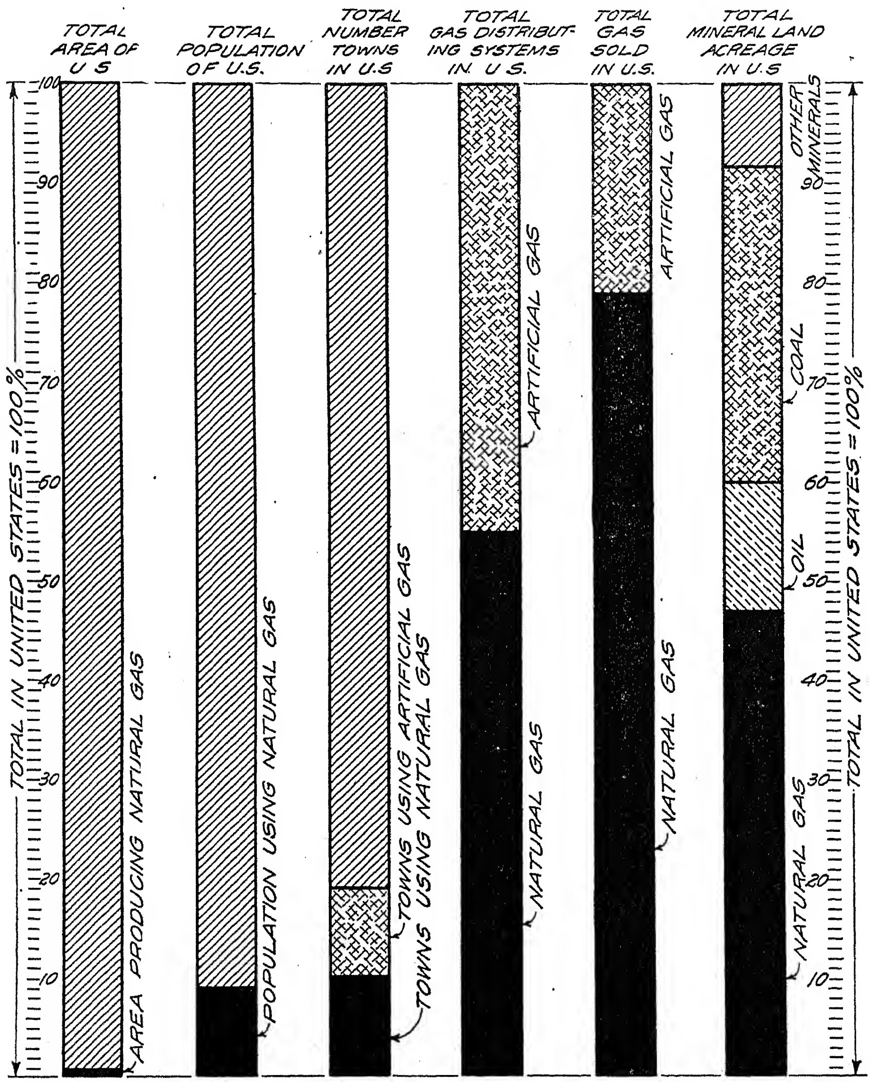


FIG. 2.—RELATIVE GEOGRAPHICAL FEATURES OF NATURAL GAS INDUSTRY IN THE UNITED STATES.

the very nature of things, must give its own consumers preference on account of public policy and the contractual relations existing between such consumers and the gas company.

5. The consumer's interest and rights extend clear back to and depend on the gas wells and reserve acreage that the producing company maintains to insure an adequate present and continuous future service.

6. Large interstate natural gas business—which cannot be burdened or interfered with by any State—has been developed as shown in Fig. 1.[1]

7. The relative geographical features of the natural gas business in the United States are startling, as shown by Fig. 2.

8. The hazard in the natural gas business is greater than that in most mining operations or in any other utility service. It is more difficult to determine the outline and volume of a natural gas formation than it is to make a similar determination for coal or other minerals. In fact, it is impossible from surface indications to determine whether gas can be found, and even a large well is no sure indication of a paying field, as it frequently happens that prolific wells are surrounded by dry holes or unprofitable territory, and the wells are short lived.

9. Gas companies discharging their legal duty to their domestic consumers cannot depend upon the initiative of the occasional producer for a supply of gas, but must depend upon their own initiative in order to maintain proper field operating conditions and an adequate reserve acreage for future development to insure a good service to their patrons. Experience has many times shown that satisfactory continuous service to the consumer can be rendered only when the *production*, *transportation*, and *distributing* features are properly co-ordinated. To subordinate the transportation side of the business to either the producer's or the large industrial consumer's interest is indefensible.

10. Even though natural gas is a mineral it requires constant attention from the time it is reduced to possession at the bottom of the well, and embodies an unbroken chain of service features until it is burned at the consumer's fixtures.

11. Less than 1 per cent. of the total number of natural gas consumers of the United States are industrial users, yet these users take over 65 per cent. of the total gas used, as shown in Fig. 3.

12. The 1,621,557 domestic consumers in the United States have at least $150,000,000 invested in service connections, house piping, and gas-using appliances.

13. To make common carriers of natural gas lines will destroy the policy of conservation and greatly increase the waste of natural gas in industrial work, thus tending to soon exhaust the available supply and leave the householders with large investments of appliances and pipes which will be useless, owing to the permanent failure of the gas.

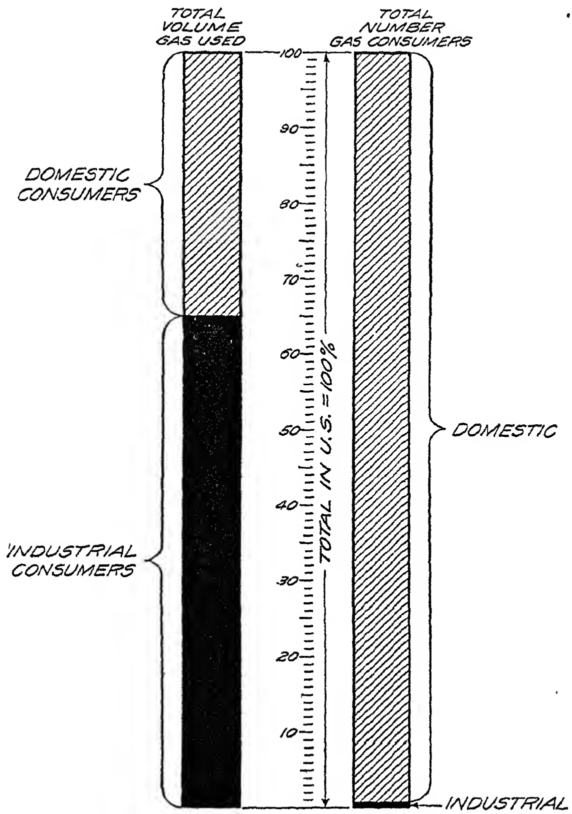
14. Gas may be produced from a small territory and a few wells at a

[1] Figs. 1, 2, and 3 are based on the latest U. S. Geological Survey and U. S. Census statistics.

much lower cost than is possible where the producer so develops his property as to hold a large acreage in reserve in order that a continuous gas supply may be guaranteed for a period of years.

The important ethical features of this common carrier problem are:

1. The domestic consumer's interests are superior to the industrial consumer's interests. This is because it is an easy matter to install



IG. 3.—RELATION OF DOMESTIC AND INDUSTRIAL NATURAL GAS CONSUMERS.

industrial appliances for burning solid fuel satisfactorily, but practically impossible to do this for the domestic consumer. Natural gas, being superior to any man-made product, is ideally adapted for domestic service, and ought to be conserved for this, rather than used in ordinary industrial operations.

2. Natural gas service to the domestic consumer is one which in no sense bears any relation or sustains any connection to the duties of a common carrier.

3. Natural gas, although worth 50 per cent. more on a heating-value basis than artificial gas, when used for industrial work must be sold at

an absurdly low price to compete with producer gas for industrial service. For instance, it may be shown that in a producer gas plant gasifying 3 tons of (12,000 B.t.u.) coal per hour, allowing 6 per cent. for interest on investment, 7 per cent. for sinking fund, and 3 per cent. for repairs, plus operating labor, 24-hour operation, 300 days per annum, with coal at $2 per ton, natural gas must be sold at 15 c. per "M" cubic feet; and with coal at $2.50 per ton, natural gas must be sold at 18 c. per "M" cubic feet in order to compete on a price basis. In view of the fact that the average price of artificial gas throughout the United States is over 85 c. per "M," the economic waste in permitting the use of natural gas for industrial service is self-evident.

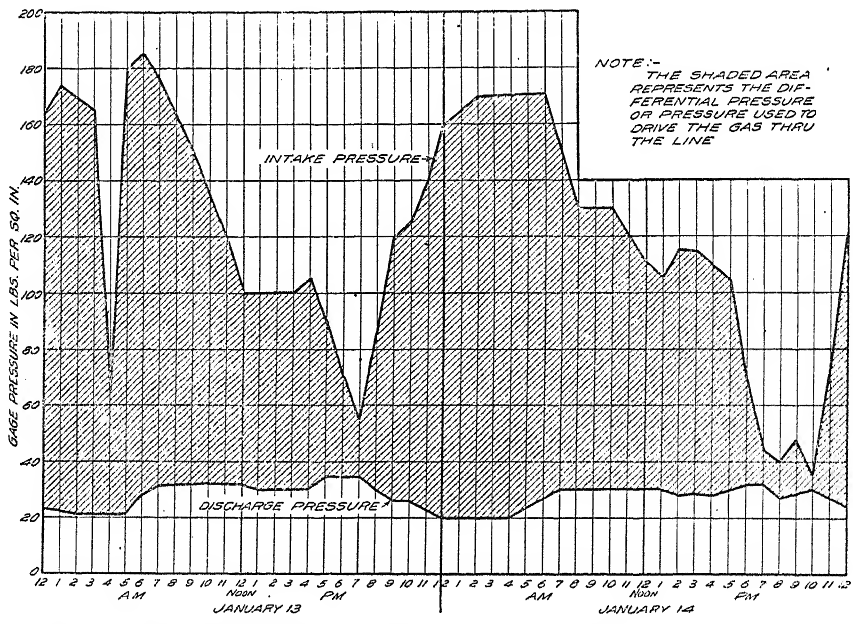


Fig. 4.—Typical Intake and Discharge Pressures of a Natural Gas Transmission Line Necessary to meet the Varying Demands of the Domestic Consumers.

4. There can be no conservation for future generations until there is an appreciation of present and future worth of natural gas service.

The leading legal features of this common carrier problem are:

1. The retail price of the gas service to the consumer is fixed by ordinances for relatively long periods.

2. That there can be no legal deprivation of property, either directly by confiscation, or indirectly by onerous burdens.

3. The contractual relations existing with present gas consumers.

The present agitation to make natural gas lines common carriers comes from three sources:

1. Small companies with no reserve acreage to take care of their normal growth or depleted condition of old and operated natural gas supplies. Many small companies are operating properties with an acreage of not over 50 acres per well. The average acreage per gas well in the United States is about 400 acres per well, and the companies that can be depended upon to render continuous service in most cases hold from 700 to 800 acres per well.

2. Manufacturers who own gas property in gas field, but who do not wish to incur the expense of carrying such gas to a point where factories are located. In several cases, after a field has been developed manufacturers have stepped in and bought a small amount of production without having any means of taking such production to the point where their factories are located. These manufacturers, therefore, expect that adjacent pipe lines serving large numbers of domestic consumers should be placed at their service in handling their industrial gas.

3. Small producers in gas field with no reserve acreage, and unable to find a local market for their gas, or unable to make the investment necessary to carry such gas to the market, are clamoring for the common carrier power in order to compel the adjacent pipe lines to act not only as common carriers in carrying their gas to a market, but also to compel such pipe-line owners to buy such gas by virtue of the economic conditions surrounding the transmission and marketing of natural gas.

It will be observed that all of these are distinctly local and selfish, and ignore the conservation principles entirely.

The engineering and economic operating conditions that must be considered and coped with in making common carriers of natural gas lines are:

1. Gas can go in *one* direction only. This makes a common carrier service for a pipe line entirely different from a common carrier service for a railroad, where transmission may be carried on in two directions.

2. Capacity of transmission lines is rigidly fixed, and will not stand any overload. This has a marked effect in taking care of peak loads, in contradistinction to railroads, which may run extra trains to carry extra traffic.

3. Natural gas service is instantaneous. There can be no delays in rendering service, as is possible (and universally practiced) in other transmission agencies, such as railroads and traction lines. For instance, a railroad can very easily start one hour late in case of congested traffic, but a natural gas service that delivers gas for cooking breakfast one hour after the consumer needed it, would not only be valueless to the consumer, but would not be tolerated in any community. This instantaneous

feature differentiates natural gas service from all transportation utilities and common carrier agencies.

It may be argued that as between a domestic consumer and an industrial consumer, the domestic consumer could be given preference in cold weather, but sudden changes in temperature would not permit the transfer from the manufacturing to the domestic consumer in time for the protection of the latter.

4. While it has been urged that gas transmission companies be obliged to build additional lines so as to care for all common carrier gas offered them, it is patent that should this be done the company would be burdened with a large indebtedness, with no assurance of continuous common carrier business, because of the uncertain life of the wells from which the common carrier gas would be offered. The well-known common law doctrine that "a utility cannot be forced to make an expenditure unless there exists a reasonable expectation that the income from such expenditure will justify the investment made" refutes this contention.

5. Since the size and length of the transmission line remain stationary, the only variability possible in taking care of a large fluctuating load is to vary the pressure on the line within the strength limits of the pipe. Fig. 4 shows the practical difficulties in taking common carrier gas into transmission lines on account of the great variation in pressure conditions necessary to insure satisfactory service to the consumers at the delivery end of the line. The pressure on the line that is to receive the gas must, obviously, be lower than the well pressure, or else artificial means must be provided to increase the pressure of the gas that is to be injected into the transmission line.

6. The market for natural gas is not fixed, but varies largely with the season of the year, time of day, temperature of atmosphere, locality, and consumer's caprice in using or not using gas on his premises.

7. Gas consumers will not contract for or agree to use a fixed amount of gas each day, but are entitled by law to take gas as they need it. With industrial consumers the consumption is controlled by business conditions, and plants may be shut down for days at a time, or work over time, without any definite arrangement with the gas company for such fluctuation in service demands. From this, it is evident, from the very nature of the case, that a consumer cannot and will not contract for a definite supply of gas from some shipper, as he cannot tell the shipper how much to forward through the common carrier lines, or when to make deliveries.

8. Leakage in transit must be taken care of, either in the rate paid for such transmission or by allowance for shrinkage at the delivery end.

9. Storage facilities are not commercially feasible for storing natural gas at the intake end, in transit, or at the delivery end of the transmission line. For instance, an 18-in. pipe, 1 mile long, at 300 lb. pressure, will

store but 200,000 cu. ft. of gas as delivered to the consumer at 4 oz. pressure.

10. Since the gas in transmission will be thoroughly intermixed, if the quality of the common carrier gas received by the common carrier is different from that delivered, a correction will have to be made for this.

11. The volume of gas taken into and discharged from the common carrier line must be accurately determined. Gas being volatile and invisible cannot be transported or identified or measured in bulk as coal or oil or other commodities; and apparatus for measuring gas in large quantities is expensive to install and operate. Furthermore, the errors in gas measurement, due to defects in the apparatus or the calculations based on the apparatus readings, are not apparent as in other commodities, and after the gas has passed the meter the volume cannot be checked to detect errors in measurement or settle disputes, as is possible with ordinary commodities.

12. Where common carrier gas is delivered to and removed from a common carrier line, it would be necessary to know:

(a) Specific gravity of gas;
(b) Pressure of gas;
(c) Temperature of gas;
(d) Quality of gas.

The first three are necessary in order to determine the volume. The quality of the gas from different places may vary considerably; thus, there may be a variation of several hundred heat units per cubic foot in the heating value. Occasionally freak wells produce large amounts of sulphur which, if introduced as common carrier gas into the main line, may vitiate the supply in many communities. It is also a well-known fact that gas as it comes from the wells contains an uncertain quantity of moisture and frequently salt water, which, if not properly handled in the field, will get into the main lines, causing damage by lines freezing up and water interfering with the action of regulators and meters.

13. A common carrier natural gas line would be limited to handle *one* commodity; whereas railroads can handle every known commodity.

14. Common carrier natural gas lines can have no extensive interconnecting service with other lines; whereas, every railroad can handle commodities from every other railroad.

15. The transportation of natural gas is a *local* business, naturally centralized in the fields of production, the deliveries being made near those fields, and not throughout the United States, as are other commodities. The limited area producing natural gas, and limited population uslng natural gas in the United States, are emphasized in Fig. 2.

16. Features Nos. 1, 2, 3, 13, 14, and 15, just mentioned, emphasize a common error made in comparing natural gas transmission lines with railroad transportation systems, and the fallacious reasoning therefrom

that because railroads are common carriers, natural gas lines can also be made common carriers.

In conclusion, the converting of natural gas transmission lines into common carriers:

1. Presents many features that are impossible, and none that are feasible or expedient.

2. Could not require a company operating a pipe line to pick up gas anywhere along its line and take it to a market except under the *legal*, *engineering*, and *economic* conditions herein defined.

3. Could not require the pipe-line company to find a market for the gas.

4. Would so disorganize the existing business as to make it impossible to render satisfactory continuous service to either domestic or industrial consumers. This would be true regardless of what might be charged for carrying this common carrier gas.

5. Would make the consumers—especially the domestic—subordinate to *occasional producers;* that is, to men who have no intention of following the business of hunting for gas for future service, but would be interested only in finding a good market, at the expense of others, for such gas as might be found as a result of an occasional venture.

6. In all cases, where tried, will impair and usually destroy the cooking, heating, and lighting service of the domestic consumer.

7. Would greatly increase the amount of gas used for manufacturing purposes, thus hastening the day when natural gas will be merely the memory of a wasted and unappreciated resource.

8. Could be based only on distinctly local and selfish interests, and would have to ignore entirely the broad public interest in an effective and continuous service and a future generation's equity in a conserved fuel supply.

The Origin of Petroleum

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TRANSLATED BY R. W. RAYMOND, NEW YORK, N. Y.

(New York Meeting, February, 1914)

APART from the hypothesis of a cosmic origin (which failed of acceptance because it was not adequately supported by facts), the only important controversy concerning the origin of petroleum has been, for a long time, between the advocates of inorganic and of organic origin respectively. Each of these theories has had a long history of development, and is still being perfected, under the influence of two causes: (1) the increasingly extensive and thorough study of the oil-fields (of which new examples are periodically discovered and opened); and (2) the progress of synthetic experiments devoted to this question. Moreover, the advance in our physical and chemical knowledge of the properties of this peculiar natural product has necessarily modified all criticism of conflicting views.

I. The Hypothesis of Inorganic Origin

That the notion of an inorganic origin of petroleum, first set forth by Berthelot in 1866, and afterward ingeniously developed and formulated by Mendelejeff, should thus have proceeded chiefly from chemists, is quite natural; for the question was one of *possible* chemical processes in the earth's interior, and of imagined chemical reactions to be verified by experiment. Hypotheses of this kind were suggested by many chemists, of whom two, P. Sabatier and J. H. Senderens, may be specially named by reason of their highly interesting chemical experiments.

Among geologists, Mendelejeff's hypothesis was received at first with much interest and favor; for it rested on the assumption of a central terrestrial mass of iron carbide, and the geologists had good reasons for adopting that assumption. Yet comparatively few of them attempted to furnish geological proofs of the hypothesis: the majority either silently believed in it, or for one or another reason rejected it altogether.

An apparently weighty support of Mendelejeff's view was furnished by the American, G. F. Becker, who found in the oil-regions of the United States important and abnormal disturbances of the isogons of terrestrial magnetism, and inferred that in these regions the central iron mass must

come nearer to the surface than elsewhere. To my mind, the better explanation is, that in these oil-fields great quantities of magnetic iron have been placed. All iron pipes, especially when set vertically and hammered, notoriously become magnetic; and this is the case with the tubings of the oil-wells—sometimes to such a degree that iron screws, lowered by ropes into the bore-holes, are so strongly attracted by the iron linings that they stick fast, and will not descend further. Moreover, the disturbances of the isogons are not uniform—a circumstance easily explained by the varying amount of iron tubes. Finally, violent irregularity of these curves is shown in places where deposits, either of oil or of magnetite, are not known.

Mr. Becker's conclusions were disputed by W. A. Tarr for other reasons.[1]

The most zealous advocate in America of the inorganic origin of petroleum, so far as I know, is Eugene Coste, of Toronto, who has collected with praiseworthy industry all the facts which support this hypothesis. To give to his many arguments the serious, thorough, and critical examination which they deserve, is the principal purpose of the present paper, as will be seen further on.

During recent decades, no European geologist of authority has advocated the inorganic origin of the petroleum occurring in large deposits.

II. The Hypothesis of Organic Origin

As regards organic origin, the view may first be mentioned, that petroleum is the product of distillation from coal—from which, in fact, artificial distillation had obtained photogene and other products having considerable physical resemblance to kerosene. This view was first expressed in Europe by F. von Beroldingen (1778). Von Kobell, Anstedt, Leon Malo, Romanowsky, Noeggerath, Huguenet, v. Hochstetter and others accepted the hypothesis; but the proofs adduced by v. Beroldingen were soon recognized as inadequate. Since petroleum often occurs not underlain by coal-beds—occurrences of coal and oil being, in fact, usually (as on the northern border of the Carpathians) mutually exclusive;—and since, moreover, the distillation-products of coal are entirely different from petroleum chemically (as Baron Reichenbach proved, as early as 1833), this hypothesis had to be abandoned. So far as I know, it received no support in America, because in Pennsylvania, the mother-land of the oil-industry, there were no coal-beds under the deposits of oil.

Animal Origin

Hypotheses of an organic origin were thus narrowed to the direct transformation of animals or plants to petroleum. Already in 1794, Haquet suspected that the oil of Galicia came from marine mussels, "dis-

[1] *Economic Geology*, vol. vii, No. 7, p. 647 (Oct.–Nov., 1912).

solved" in salt water. L. v. Buch, Quenstedt, Volger, Naumann, Dufrenoy, Posepny, Verbeck, Fennema, and many other eminent geologists, accepted this hypothesis, mostly in view of the circumstance that the bituminous rocks carry the fossil remains of animals. Bertils found in the Kuban district of southern Russia, in a bunch of mussel-shells, a substance partly "petroleous," partly animal remains still undecomposed. R. A. Townsend reported a similar observation from the Tertiary oyster-banks of Assam, in Asia. Ch. Knab somewhat extended the hypothesis; and in North America it found in Whitney, for the petroleum of California, and the brilliant Sterry Hunt, for the oil-deposits in the ancient limestones of Canada, Pennsylvania, and Ohio, its most influential advocates, with whom others allied themselves.

When, in 1876, I visited the oil-fields then under exploitation in the eastern United States and Canada, the question of the genesis of these deposits received my earnest attention. I adopted the hypothesis of their animal origin, and in my report of this journey, entitled, *Die Petroleumindustrie Nordamerikas,* I briefly argued in its favor. Since that report was the first account given in the German language of the geological, technical, and commercial features of this interesting and economically important field, the hypothesis of animal origin (as well as the theory of anticlinals, advocated by me) was tested by observations in the European oil-fields, and, confirmed by geologists such as Tietze, Paul, Uhlig, O. Fraas, v. Gümbel, H. Credner, C. Zinken, and many others, it continued to win more and more advocates.

In 1888 appeared my book, *Das Erdöl und seine Verwandten,* in which I examined critically all the genetic hypotheses known to me, and not only demonstrated that of animal origin, but pointed out certain important factors in the process of transformation, particularly the comparatively low temperature and high pressure, as indicated by geological evidence. An important landmark in genetic hypothesis was thus established, furnishing for the guidance of synthetic experiments two important conditions of the transformation of animal bodies into petroleum.

A few weeks later, C. Engler, of Karlsruhe, tested my theses experimentally, by heating in retorts, under a pressure of 10 atmospheres, and to a temperature of from 300° to 400° C.,[2] first fish-oil, and afterward fishes and mussels. He obtained in this way a product very like petroleum, from which he isolated several members of the methane series. My hypothesis, thus further corroborated, became a theory, known as the Engler-Höfer theory, since both of us had equally contributed to its establishment. It won the support of chemists as well as geologists—whose numerous names it is not necessary to catalogue here.

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[2] It is well known that time may replace temperature, so that nature performed the transformation at lower temperature. Moreover, processes of fermentation are involved, and these often produce very high temperatures.

It is noteworthy that the geologist and the chemist must co-operate in the solution of genetic problems in geology—the former by investigating the natural conditions attending a given formation, while the latter synthetically performs the process itself. Only when thus confirmed is the theory adequately established.

Vegetable Origin

A great additional service rendered by C. Engler was his tireless labor through many years in the investigation of the various transformations undergone, up to the present time, by the original materials and primary forms of petroleum—a labor which still further perfected the Engler-Höfer theory. These investigations showed that vegetable fats also, by dry distillation under high pressure and at comparatively low temperature, could be transformed into petroleum, as American chemists (Warren and Stoner, Sadtler, etc.) had already proved. Our theory could therefore be extended to include those plants which, like animals, contain fats and albumens, but no cellulose—namely, the microscopically small diatoms. T. Fegräus and A. F. Stahl, who first pointed out this source of petroleum, were followed by G. Krämer and A. Spilker, and, still later, by Potonié. This hypothesis is applicable only where, as in California, the minute and delicate siliceous shells of these fossil algæ occur in connection with oil-deposits.

Many American geologists and chemists like Lesley, Newberry, Ashburner, Shaler, Orton, Peckham, Mabery, etc., had already either advocated a common animal and vegetable origin, or (like the two highly esteemed investigators last named) assigned an animal origin to the nitrogenous California product, and a vegetable one to the non-nitrogenous oil of Pennsylvania. The contrary appears, however, to be the truth, since the diatoms are found in Californian, and not in Pennsylvanian, oil-fields. Probably the advocates of the double origin were not thinking of the microscopic vegetable forms at all; they speak in a general way of "plants." But the more highly organized plants contain cellulose, which would leave after distillation a carbonaceous residuum, such as is not found in petroleum and its deposits. For this reason, the above hypothesis, once so generally favored, could not be finally accepted.

According to our present knowledge, the original material of petroleum is principally fat, and subordinately wax, resin, and albumen. These substances, especially fat and albumen, occur chiefly in both the lower and the higher animal organisms. Petroleum, therefore, is mainly of animal origin, though it may have been formed, here or there, from fatty plants, particularly diatoms.

The foregoing is a brief review of the development and present condition of our knowledge on this subject. In Europe, as in America, most

geologists and chemists hold to the organic genesis of petroleum, and L. V. Dalton,[3] in his thorough essay, declares himself an adherent of the Engler-Höfer theory.

III. The Hypothesis of Volcanic Origin

As already observed, Eugene Coste, of Toronto, seems to be the most zealous American defender of the inorganic origin of petroleum. Three of his papers on this subject lie before me: (1) The Volcanic Origin of Oil (*Trans.*, xxxv, 1904, p. 288); (2) The Volcanic Origin of Natural Gas and Petroleum (*Journal of the Canadian Mining Institute*, vol. vi, 1903, p. 73), and (3) Petroleums and Coals Compared in Their Nature, Mode of Occurrence and Origin (*idem*, vol. xii, 1909, p. 273). He sees in petroleum "the product of volcanic solfataric emanation." In the following critical examination of his proofs, I refer chiefly to the interesting paper last named, which is the most recent, and, moreover, takes account of the arguments previously stated in the two others.

I must express in advance my surprise at his statement (p. 275): "The petroleum series includes all the natural hydrocarbons with the exception of the marsh gas." This hydrocarbon is found in every petroleum, though it escapes as a gas very rapidly, as soon as the oil is exposed. Of natural gas, it is generally the essential constituent.

The Proofs Advanced by Coste

Mr. Coste says in one of his papers: "The vital point is to actually show the carbon and hydrocarbon in the igneous rocks, lavas and emanations proceeding from these internal fluid magmas."

As illustrative instances, he cites (on p. 278 and following pages of his latest paper) the following:

1. "Oil in crystalline gneiss: In Placerita Canyon, five miles east of Newhall, Los Angeles county, California, a very light oil, almost naphtha, of a gravity between 50° and 60° B., is produced from crystalline gneisses which overlay the San Gabriel granite."

According to the investigations of G. H. Eldridge and Ralph Arnold, this so-called crystalline gneiss is not gneiss at all, but a metamorphic crystalline schist, perhaps Jurassic, and hence by no means an Archæan rock which could possibly be regarded as eruptive. It is a metamorphosed sedimentary, and can give Mr. Coste no help—rather the contrary. The oil of this locality may be in its primary deposit, or, more probably, it may have found its way thither from the neighboring Tertiary oil-field.

2. "Oil and bitumen in the quicksilver deposits of California."

[3] *Economic Geology*, vol. iv, No. 7, p. 608 (Oct.–Nov., 1909).

Being unacquainted with the geological relations of that district, I can offer no suitable explanation of this occurrence, and will only remark that these bitumens may have been extracted and transported from deeper bituminous rocks by the ascending ore-bearing solutions. Spirek ascribes to bituminous rocks the occurrence of bitumen in the Tuscan quicksilver mines. Since the bitumens occur very seldom in ore-deposits—particularly in deep-seated veins,—they cannot be regarded as a general product of deep volcanic zones. They must have a purely local cause. At all events, such scanty occurrences of bitumen of all sorts prove nothing as to the formation of rich petroleum-deposits. This has been emphasized by Prof. Dr. L. Mrasec, of Bukarest, who is inclined, moreover, not to admit a deep source for the rare occurrences of bitumen in ore-deposits.

3. "Graphite and natural gas in the metalliferous vein of Silver Islet, and graphite in the veins at Cobalt and Ducktown, Tenn."

To these instances also, what I have already said is applicable. No one would dare to infer from the sporadic occurrence of graphite in mineral veins that *deposits* of graphite are of volcanic origin—still less when (as in the Kaisersberg, Styria) the graphite is accompanied by plant-fossils. It seems to me equally audacious to argue the origin of the great deposits of petroleum found in sedimentary rocks, from the isolated and quite insignificant occurrences of bitumen in veins.

4. "Solid petroleums in pegmatite dykes, and other veins, associated with uranium, radium and vanadium."

We are here concerned, not with "solid petroleum" (a contradiction in terms, since petroleum is a liquid), but with a bituminous mineral, the combustion of which left an ash which, in one locality not named, contained uranium, and in another place, in Peru, contained vanadium. The remarks already made under (2) and (3) are applicable here; and I will only add that petroleum is almost entirely free from ash.

5. "Graphite, diamond and hydrocarbons in meteorites."

This phenomenon bears no relation to the origin of petroleum, nor is it at all surprising, since in the original cosmic material carbon must have been present (probably as carbonic acid), and must have been segregated in the meteoric masses, as in that of the earth.

6. "Oil and natural gas in volcanic rocks in Europe, Africa and Mexico."

These occurrences, few in number and always very small in extent, may be due to coal-beds or bituminous rocks which the volcanic eruptive broke through, distilling out and absorbing into its own mass some oil and natural gas. This distillation of bituminous material has long been practiced in the Scotch shale-oil industry.

7. "Natural gas in serpentine, Asiatic Turkey" (Chimaera).

Alexander von Humboldt suggested long ago[4] that this emission of gas might be connected with petroleum. E. Tietze,[5] who studied the phenomenon on the spot, adopts this view, and calls attention to the neighborhood of the so-called "Flysch" formation, which so frequently carries petroleum.

8. "The occurrence of oil around volcanic necks, Mexico."

This proves nothing, since the mineral oil of Mexico, and especially of the State of Tamaulipas, named by Mr. Coste, is widely distributed, and occurs both near volcanic necks and far from them. Villarello,[6] Division-chief of the Mexican Geological Institute, and one of those best acquainted with the oil-occurrences of Mexico, concludes: (*a*) that the oil comes from a marine fauna; and (*b*) that, in the districts explored hitherto, it is found only in secondary deposits, situated in highly disturbed terrain, connected frequently with basaltic eruptions. Since the volcanic tuffs are highly porous, it is not surprising that the oil, in its migration, should accumulate there in special abundance.

Of all the foregoing proofs of the volcanic origin of petroleum, only two, No. 1 and No. 8, are really pertinent to the question of the genesis of valuable deposits of oil. The rest are so insignificant that they prove nothing as to the production of oil in large quantities, and have for us only a purely scientific interest. And the two exceptions, adducing the occurrence of petroleum in alleged gneiss, and in connection with volcanic necks, have been shown, I think, to be entirely inadequate as proofs.

As a logical consequence of Mr. Coste's view, deposits of petroleum should always be found in the vicinity of volcanic eruptions. But this is not the fact. In the Carpathians, the "outer bend," through Galicia, the Bukowina, and Roumania, is free from eruptives and rich in oil, while the "inner bend" is rich in eruptives and poor in oil. At Baku, in Alsace, and in North Germany, as in Canada, New York, Pennsylvania, Ohio, West Virginia, Louisiana, Texas, etc., there are no eruptives near the rich oil-deposits. In Java, Sumatra, Borneo, and Burmah, the oil-fields are far from the regions of eruptive activity.

These weighty facts, completely contradicting the volcanic hypothesis, Mr. Coste seeks to deprive of force by the assumption that oil and gases have ascended from greater depth through fissures, and thus were deposited far from eruptive masses. But it is remarkable that the Hungarian Carpathians are much more disturbed than those of Galicia and Roumania, and are, nevertheless, poorer in oil—indeed, for the most part, contain no oil at all. The most important and profound disturbance of the Galician Carpathians—the so-called *Klippenzone*—is barren of oil,

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[4] *Kosmos*, vol. iv, Observation 51.

[5] *Jahrbuch der k.k. geologischen Reichsanstalt*, Vienna, vol. xxxv (1885).

[6] J. D. Villarello in *Das Erdöl*, by Engler and Höfer, vol. ii, pp. 643 and 650 (1909).

like its neighbor, the *Weichselbruch.* The Alps are traversed by deep faults and dislocations, many of which still make themselves disagreeably felt as seismic surfaces; yet no noteworthy oil-deposits have been found among them. At the foot of the Alps on the north, the gas-springs of Wels, in Upper Austria, are found in quietly deposited and undisturbed Miocene strata. In the rich oil-bearing flat anticlinals of Pennsylvania, I sought in vain for any dislocations worthy of mention; and not one of the intelligent "oil-men" whom I met could point me to any such thing. East of that oil-region, we find in the Appalachians mighty disturbances of all kinds—deep fissures, sharply arched anticlinals,—but no oil. At Pechelbronn, in Alsace, the slightly inclined oil-bearing sandstones were formerly mined and thus thoroughly explored, without the discovery of a single dislocation, showing that the oil was occupying its primary place of deposit. K. Kalickij[7] proved the same proposition for the oil-occurrences on the island of Tscheleken. Even the photographs accompanying his paper are conclusive.

The Objections Advanced by Coste

In order to weaken objections to his own theory, Mr. Coste urges[8] the following objections to the theory of organic origin:

1. "It cannot possibly explain the large petroleum fields below the Carboniferous."

Can the solfataric hypothesis do that? No: Mr. Coste's proofs—except No. 1 and No. 8—rest wholly upon isolated and minute occurrences of bitumen. No one has ever observed at a solfatara any accumulation of petroleum worthy to be mentioned. On the other hand, F. Quenstedt[9] has shown that 1 square mile of the bituminous Posidonia slates of Suabia, rich in animal fossils, contains 200 million hundredweight of oil. In other words, the animal remains of a single sedimentary bed can furnish enormous amounts of oil. What was possible after the Carboniferous era may have been possible before it also. Biological activity on the earth has been immense, continuous, and widespread; whereas volcanic activity has been local, and often but temporary, discharging here and there comparatively insignificant quantities of hydrocarbon gases.

2. "Neither can it explain the petroleums in the volcanic emanations of today."

No considerable quantity of hydrocarbon has ever been found in a solfatara. And where one or a few per cent. have been found, they can be referred to bituminous strata which have been intersected. Moreover, positive reports of hydrocarbons (usually given as methane, CH_4) are to

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[7] Ueber die Lagerungsverhältnisse des Erdöls auf der Insel Celeken. *Mémoires du Comité Géologique*, St. Petersburg, New Series, livraison 59 (1910).

[8] *Journal of the Canadian Mining Institute*, vol. xii, p. 295 *et seq.* (1909).

[9] *Einst und Jetzt*, p. 57.

be received with caution. The gases of the Hawaiian volcano Kilauea are often cited as an example. But when collected directly by L. Day and E. S. Shephard[10] they were found to contain no hydrocarbons at all. So this proof also fails. The small quantities of marsh-gas, produced by Brun at Geneva through the heating of certain lavas, may have formed themselves during the process through the decomposition of other gases, for instance, according to the equation

$$4\ CO + 8\ H_2 = 2\ H_2O + CO_2 + 3\ CH_4.$$

3. Nor can the organic thèory explain the petroleums "in the volcanic or igneous rocks in all parts of the world."

4. "Nor in crystalline rocks; in California and New Brunswick, for instance."

5. "Nor in meteorites."

6. "Nor in metalliferous veins."

These four points have been already discussed, and shown to be invalid.

7. "It is also at a loss to explain why the petroleum fields in every district are found grouped along certain lines and why the petroleums are found there in many horizons, while outside of the lines in just the same strata and over much larger areas all the horizons are barren."

This raises the comprehensive question of the structure of the petroleum-deposits, which cannot be treated within the limits of this paper. I will only say briefly that the oil is found along certain lines, because it occurs (1) in fissures, (2) in folds, and (3) in long-drawn channels of sand. The fissures are directly connected with the primary deposits. In folds, anticlines, monoclines, etc., the position of the oil is determined by the accompanying natural gas and water. The three substances arrange themselves according to their specific gravity, along the lines and surfaces presented by the shape of the fold. If the oil-bearing sands occur in long, slender bodies, as in Alsace, the grouping of the oil "along certain lines" is not surprising. Since the oil-deposits are coastal formations originating under special conditions, it is comprehensible that they cannot follow throughout the same geological horizon.

8. "It cannot explain either how the petroleums can possibly travel out of their supposed organic-remain source in some impervious clay or shale to accumulate in a few porous receptacles far distant laterally and sometimes hundreds and thousands of feet above, or even below as some assert, and this all through most impervious rocks and without any impelling force behind, or any cracks, joints or fissures to follow since the decomposed products of the organisms must naturally be supposed to come from the whole mass of the strata through which the organisms were and there could not be fissures, cracks and joints to all parts of the strata."

If I understand Mr. Coste correctly, this passage is directed, not so much against the theory of organic origin as against the hypothesis, so popular in America, of the regional migration of petroleum. In this re-

[10] *Journal of the Washington Academy of Sciences*, vol. iii, p. 475 (1913).

spect, I heartily agree with him. I too maintain that the migration of oil can take place only in cracks, joints, and fissures, the source of motive energy being (as has been often demonstrated) the accumulation, in the primary deposit, of natural gas under high pressure.

9. "It cannot possibly explain why the petroleums, although found today in their reservoir-rocks under strong pressures, cannot by means of that pressure, return and disperse back to their original sources; they should be able to return the way they came, nothing is to prevent them and there is plenty of pressure for the return voyage if one admits the first voyage from the organic source."

This question might be applied to Coste's hypothesis also. As already remarked, petroleum is driven by gas-pressure to a considerable altitude in fissures; and its removal leaves in the original deposit a space in which the gases collect and keep the oil above them, as, for instance, in the so-called inverted siphon, when partly emptied, the entrance of carbonic acid gas continues to maintain the height of the water in the discharge-pipe.

10. This objection, based on alleged features of the occurrence of petroleum in California, I must leave to my esteemed colleagues, Ralph Arnold, B. Anderson, G. H. Eldridge, and other distinguished investigators of the oil-geology of that State. It will possess for them no difficulty.

11. "It cannot possibly explain again, if the petroleums can travel so freely through the strata as to be able to accumulate under an anticline from organic remains deposited far and wide laterally (at least a mile or two or much more in order to allow for the quantities obtained in many fields), why they did not escape out into the free air only a few hundred or a few thousand feet away at most; the shales above the sands are not any more impervious than the shales below the sands, which on that theory are supposed to be the source of the petroleums, and if they can travel freely through the shales which are the most impervious rocks of the sedimentary series, I repeat, what is to prevent them from getting out into the atmosphere?"

This question properly concerns, not the organic origin of petroleum, but a hypothesis of its migration, advanced to explain the formation of productive deposits—a hypothesis which I reject, holding that petroleum originated in the sands in which it is found, unless it has passed through fissures to other sand-strata.

12. "It cannot account for the continual absence of petroleums in the hard parts of organisms preserved in the sedimentary strata."

Oil can be formed from the soft parts of animals under certain conditions only, among which is the exclusion of air. We find on the seashore many hard parts, such as shells and skeletons, of marine animals, from which their organic contents have totally disappeared, having been destroyed by the oxygen of the air. Since this generally finds access to dead animal matter, we find the hard parts without oil very frequently, and oil itself infrequently in comparison, because only under special favoring conditions.

13. "It cannot explain the evident non-connection of petroleum deposits with coal-beds."

Since the latter are land-formations from plants containing cellulose, while the former are marine estuary-formations from animal remains, there can be no connection between the two organic processes or their products.

14. "It cannot account for the continual association of petroleums with strong salt and sulphur waters."

Since the original materials of petroleum accumulated in marine bays, having but limited relations with the ocean, the presence of strong salt water is not surprising, but constitutes, on the contrary, a proof of our theory. Sea-water is known to contain sulphates also, which, in the process of oil-formation, can be reduced to sulphides, or even to sulphur. As a marine formation, petroleum may be accompanied by salt, gypsum, calcite, and dolomite; and this explanation of their presence seems to be more natural than that of a volcanic source.

Further Considerations

I have thus answered in detail both Mr. Coste's objections to the organic, and his arguments for the inorganic, origin of petroleum. The latter, however, constitute, strictly speaking, an incomplete statement; for he contends only that petroleum was brought by solfataras into the cooler parts of the earth's crust. Concerning the questions, *out of what* and *how* it was formed, he is entirely silent. His explanation, even if we were able to accept it as correct, goes only half way, like those of his predecessors, Lenz (1831), Rozet (1835), S. W. Pratt (1846), Choucourtois (1863), Thore (1872), Fuchs and Sarasin. It is at best a plant without a root.

Even if we had proved, or should hereafter prove (as has never yet been done), the presence in solfataras of large quantities of marsh-gas, CH_4, such gas would stream into the air, without forming petroleum. Besides, we know of no process by which CH_4 can be converted into the higher members of the paraffine series, or any member of the naphtha series. This circumstance likewise deprives the very rare occurrence of CH_4 in ore-deposits or volcanic rocks, of all significance as to the origin of petroleum.

As a sincere friend of the petroleum industry, I am heartily sorry that I must reject Mr. Coste's emanation-theory; for, if it were true, we might expect our petroleum-supply to prove inexhaustible, new quantities being continually furnished by solfataric activity. Unfortunately, that is not the case.

Mr. Coste mentions an occurrence of hot water with petroleum in Texas. This is a purely accidental phenomenon; since neither in the great

Yellowstone region of thermal springs nor in any of the European hot springs has petroleum, or even marsh-gas, been observed.

Why are oil-deposits lacking in the highly fissured true Archæan rocks of Scandinavia, Bohemia, the central Alps, the Appalachians, etc.; and why do they appear first in the sedimentaries deposited at a time when the earth had become populated with organisms? This can be construed only as a proof of the organic origin of petroleum.

If this oil had ascended from great depths, it would have impregnated all porous strata. But, on the contrary, we find repeatedly, between two oil-bearing horizons, porous rocks containing no oil, like, for example, the Jamna sandstone in the Galician Carpathians. Underlying the oil-sands themselves, there are porous, yet barren, rocks.

If petroleum were the product of distillation at high temperature, it could not contain any primary paraffine, and it would be richer in olefins. Neither of these conclusions is confirmed by the facts.

The occurrence of free nitrogen (not in the form of air) in many petroleums and (often in considerable amount) in natural gas, cannot be explained by any volcanic hypothesis, but furnishes another strong proof of organic origin. The same may be said of the optical properties of petroleum, and of the presence of cholesterin, which seems to be a condition of the polarization, and is a special indication of animal origin. Moreover, the high-molecular pyridin bases, observed in many oil-regions (Galicia, Alsace, Baku, Fergana, Roumania, Sumatra, California, Egypt, Algiers) speak conclusively against a volcanic, and in favor of an organic—particularly an animal—origin. The general chemical character of petroleum as an unstable mixture of hydrocarbons bears similar testimony against any supposed pyrogenic process at high temperature.

All geological and chemical facts concerning the occurrence of petroleum bear unanimous witness in favor of its organic origin, and hence conclusively against its production from inorganic substances, and the collateral hypothesis of emanation. The doctrine of the volcanic origin of petroleum deposits must therefore be pronounced to lack scientific foundation.

To demonstrate this fact in a review of the publications of Mr. Coste, one of the most meritorious and zealous representatives of that hypothesis, has been the purpose of the foregoing remarks. Hence I have adduced proofs of organic origin only so far as they contradicted the opposite view. For a detailed exposition and defense of the former theory, I refer to my two books: *Das Erdöl und seine Verwandten* (3d ed., published by Vieweg at Braunschweig in 1912), and *Die Geologie, Gewinning und der Transport des Erdöls* (published by Hirzel at Leipzig in 1909), the latter of which constitutes vol. ii of the comprehensive monograph issued by Engler and myself under the title, *Das Erdöl.*

DISCUSSION

A. F. LUCAS, Washington, D. C.—I have long held the opinion that igneous rock in the form of laccoliths, batholiths, or sills may underlie the salt domes of Louisiana, Texas and elsewhere, and have advanced the hypothesis of the volcanic origin of these domes. In the face of the apparently conclusive arguments presented by such authority as Prof. H. v. Höfer, it takes much courage or almost convincing proofs to still advocate such an hypothesis, but when one travels over the Coastal Plains of Texas, Louisiana, and Mexico, one needs still more courage, as there are certainly no visible evidences of vulcanism for hundreds of miles, only perfect and level plains of unconsolidated sedimentary materials.

Over these plains there rise some elevations of various heights which by comparison with the wide extent of the plain may be likened to a pin prick on the floor of this room. A series of these elevations appearing in perfect alignment northwest to southwest are now known as the Salt Islands in Louisiana, and others scattered through the Coastal Plain are known as hills, mounds, or domes. On some of these elevations there exude from low depressions solfataric emanations from pools of acidulated water, while on others there are no indications of disturbances coming from below.

I pioneered the drilling on all these islands and most of the domes and invariably found them to be underlain in whole or in part by salt masses. This is the case also at Belle Isle, Anse la Butte, Spindletop, Bryan Hights, etc., on whose domes oil and sulphur were also found.

On Belle Isle strong indications of solfataric emanations were more apparent than on other domes of the series, and therefore this property was more extensively exploited than any other, with the exception of Spindletop, first for salt, and then for oil.

I have held the opinion with Mr. Coste that the emanations of gas through these domes constitute evidences of volcanic origin, and I have in consequence been desirous of making a practical demonstration to prove, if possible, whether or not the salt masses of the Coastal Plains rest on volcanic plugs. Accordingly I induced I. N. Knapp to drill a deep test well to ascertain, first, the total depth or thickness of the salt mass, and second, the character of the rock formation upon which the salt rests.

This was easily said, but not easily done, as in one of the early bore holes drilled by me some 18 years ago at Jefferson Island, for Joseph Jefferson, drilling was carried to a depth of 2,100 ft. without passing through the salt. The total thickness of pure rock salt, as far as explored, was nearly 1,900 ft.

Since the drilling of the discovery well by me on Spindletop, a salt dome, in 1901, creating a new precedent in oil exploration on the Coastal Plains, many attempts have been made to find oil by drilling on all sorts of elevations, however slight, in hope to strike another Spindletop, which was only 12 ft. above the surrounding prairie. In most instances the drill encountered either rock salt or dolomite which continued to considerable depth. As oil was not supposed to be present below these substances, the drill was stopped and the well abandoned.

There was therefore at that time no precedent at hand and no geologist willing or able to advance a possible hypothesis as to how deep the salt mass may continue, or upon what kind of rock it might rest.

Many theories and hypotheses have been advanced by students or geologists to account for the origin of these wonderful salt masses. In studying the interior of salt mines which have been carried to a depth of several hundred feet, and also in considering the perimeter of the salt domes, one cannot help concluding that the salt was not deposited by evaporation, but must have been deposited by saline waters ascending from great depths. In looking over a vaulted chamber in a salt mine of the Coastal Plains one is struck by the dazzling whiteness of the salt, which is interspersed, however, by dark streaks resembling the grain of oak or chestnut. These dark streaks are caused by very fine grains or stringers of gypsum, making it appear as if the whole mass was at one time in a plastic condition.

The Knapp well at Belle Isle passed through the salt at about 2,900 ft. and then continued in calcareous rock to a depth of 3,171 ft. At this point the drill encountered a formation so hard that no impression could be made with the ordinary fishtail bit and consequently no sample of the rock could be obtained. While endeavouring to obtain a diamond drill outfit, the well (which was at that time in great distress owing to gas pressure and caves) was lost and no other deep well has been drilled since that time.

The information this well gave is or should be gratifying, for although it failed to furnish a sample of the hard rock at 3,171 ft., it is likely that it would have proved to be an igneous rock, probably basalt, for in all my experience no sedimentary rock, even a hard limestone, would have worn the drill as this rock did. A new and very hard drill was repeatedly lowered and efforts made to drill into it, but with the same result.

This well has, however, established certain facts, to wit: (1) the total depth of the rock salt, a thing heretofore unknown; (2) that oil and gas under heavy pressure exist under the salt; and (3) the existence and beginning of a very hard formation, necessitating better drills than the best fishtail bit then in use (possibly a Sharp & Hughes drill might cope with the situation, and if not that, the Calyx drill, or even a diamond

drill); (4) that the depth so far attained is not at all beyond limits of economic drilling as practiced to-day, and that with a proper drilling outfit and heavy casing a station could be made to set the casing on the extreme bottom in order to proceed unhampered by gas and caves through a greater depth, say at least 6,000 ft. This would give a latitude of nearly 3,000 ft. of territory still to be explored; and in a zone of such wonderful activity very important facts may be brought to light which may prove conclusively whether or not petroleum comes from igneous rock and consequently is of volcanic origin.

Through the many holes drilled on this dome to ascertain the dip of the salt, there were invariably encountered, overlying the salt, lenses of limestone containing from 10 to 35 per cent. of sulphur. In some instances the drill dropped several feet, thus showing that the limestone is cavernous. This is also evidenced by the fact that in some wells many wheelbarrows of clay were dumped in the hole in the effort to get return of the drill water.

Nearly the whole mass of the salt seems to have been impregnated with gas and oil globules, which are often visible without the aid of a lens. In emptying a bailer of its fragment of salt into a trough, the fragments in liquefying would pop like so many jumping jacks, proving that the salt containing the gas and oil is under heavy pressure. Throughout the drilling of this well gas under heavy pressure, oil, impure gypsum, anhydrite, and sulphur were obtained, and at a depth of 2,745 ft. a ledge of magnetic iron. Where did this magnetic iron come from? Certainly not from the outside of the dome, which is surrounded and hemmed in by muck sand, gumbo, gravel, etc.

The cost of a well like this was of course high, because one did not know what to expect next, but now within the limit of depth attained by this well the cost would be considerably less, and if proper preparations were made the drilling of a well to say a depth of 6,000 ft. would not be excessive, considering the possible results that might be attained.

William C. Phalen, Washington, D. C.—What is the approximate thickness of calcium carbonate and gypsum after you passed through the salt?

A. F. Lucas.—We have the data; to wit, from 2,900 to 3,171 ft.

William C. Phalen.—It seems to me that these are normal solutions. We should have a calcium carbonate, then gypsum and salt on top. You mentioned the presence of these substances.

A. F. Lucas.—Yes, within the confines above given, although some may have come above the salt, as the well was not cased at this point.

I. N. Knapp, Ardmore, Pa.—We established the fact that there was a ledge of magnetic iron. I think there was 4 ft. of magnetic iron at a depth of 2,745 ft. The bit wore faster than the ore. The magnetic

iron consisted of small particles cemented together, and it fairly hissed when it came out of the hole.

George S. Rice, Pittsburg, Pa.—Was an analysis made of the gas?

A. F. Lucas.—No, sir; we were after more valuable or important data than the composition of the gas.

C. W. Washburne, Washington, D. C.—In calling attention to this salt, which Captain Lucas said hopped about when it was thrown on a shovel, that is what they call knister salt. If this salt is put in water it practically explodes, and blows the water around. The gas in it is under very high pressure. It has been measured, and the pressure is under several hundred pounds. These gases could not have gotten in there under steam or water pressure. That salt crystallizes under ground and the gas gets into it at the time it crystallizes. It would crystallize in a shallow dune, and it formed there under pressure of the rocks, and the gas, of course, is under pressure still.

Eugene Coste, Calgary, Canada.—I am sincerely grateful to Dr. v. Höfer for this paper discussing the origin of petroleum, and opposing the view of that origin which I have supported on many occasions since 1900. It is only by such discussions that all the facts and arguments in the case will be brought clearly forward; the members of the Institute, mining engineers and geologists, are the best of jurors to decide on both the facts and the arguments; and thus we may hope to arrive at the solution of this scientifically and economically most important problem.

Before answering Dr. v. Höfer's points against the solfataric volcanic origin, I may be permitted to *résumé* what I understand from his paper to be his own views, and what he frankly states as his position on the question. He narrows the origin of petroleums to the direct transformation of animals or fatty plants (such as diatoms) without cellulose; and he considers that the organic matter was originally in the "sands" in which the petroleums are now found, unless in the cases where petroleums have passed afterward through fissures to other sand strata. Dr. v. Höfer also considers these sands to be coastal marine formations, deposited in shallow bays of the sea, where, under special favoring conditions, the oxygen of the air did not destroy as usual the animal or fatty plant matter, which was therefore entombed, and afterward through the agency of long time was gradually distilled at low temperature and under high pressure, and became petroleum.

The clear statement of these views forcibly suggests at once the following objections to them:

I. Why is not this process in active operation in the world to-day? Why can we not abundantly verify it, and witness it in numerous cases in

some of the millions of shallow bays of the sea teeming with life, where sands are being deposited to-day, and have been deposited in recent ages under similar conditions? It is not enough to cite in support of this hypothesis a very few cases, in which empty shells, or organic matter partly decomposed, were evidently impregnated with petroleums by seepage through fissures or seams from underlying reservoirs.

II. It is also erroneous to say that this hypothesis (p. 483 of Dr. v. Höfer's paper) was accepted by eminent authorities, "mostly in view of the circumstance that the bituminous rocks carry the fossil remains of animals." As a matter of fact, the fossil remains of animals or plants are found mostly in shales which are, as a general rule, absolutely barren of petroleums. It is only very occasionally, surely not in 1 per cent. of the cubic contents of the strata, that bituminous rocks, or rocks (either shales, sands or limestone) containing petroleums, are found; and, as a rule, these spots are comparatively small and are very poor in fossils. The other 99 or more per cent. of the strata really contains the fossil beds; and these fossil beds, as is well known, are barren of petroleums. Although some of these shales may be carbonaceous, they are not bituminous or petroliferous.

III. This brings one to the third serious objection to the view of Dr. v. Höfer, namely, that the "petroliferous sands" are so poor in fossils, and the petroliferous sand-reservoirs are so limited in extent and thickness, with impervious rocks all around them (since we find heavy gas pressures in these reservoirs), that the enormous quantities of petroleums they have produced cannot possibly be accounted for in that way. I will cite only one instance: viz., the example of the small dome of Spindletop at Beaumont, Texas, where from a little over 200 acres, some 50,000,000 barrels of oil have been produced up to date. The oil "sands" under that dome are secondary crystalline limestone or dolomite masses, found only under the dome area of a little over 200 acres, the surrounding strata being impervious clays and sands and "gumbo" beds, with fossils but without oil. The secondary crystalline limestones or dolomites under the dome, containing these enormous quantities of oil, are not fossiliferous; but even if they were, the oil in them could not be indigenous in such quantities, and undoubtedly came up the chimney under the dome from below, since it cannot have come from the impervious sides.

This reasoning from indisputable facts, patent in many fields, long ago forced the American geologists to the conclusion that the petroleums cannot have been produced in the sands they now occupy. On the other hand, most of the American geologists, and many others, conceive a regional migration of oil out of the impervious surrounding sediments into the sands—which, of course, is also impossible. Dr. v. Höfer agrees with me (p. 490 of his paper) that there is no possible regional migration of oil through the pores of such impervious clays and shales as surround

the "sands," and "that the migration of oil can take place only in cracks, joints, and fissures;" but his primary deposits, "the porous sands," are evidently altogether too small in cubic capacity, and too poor in organic contents, to furnish the enormous quantities of petroleum which have actually been produced from them.

Moreover, in the different fields of the world we can trace these primary sand deposits of Dr. v. Höfer lower and lower down in the geological scale, until we find them not only in the Devonian and Silurian but also in the Cambrian (Potsdam sandstone in N. Y. State) and in the crystalline rocks (Newhall, Cal.). This forces us to admit a still lower source, namely, the volcanic magma; and when these volcanics everywhere give so much evidence of containing large quantities of hydrocarbons either in their associated solfataric gases or in the lavas themselves, why should we reject that source to which we are forcibly led by the full consideration of the geological evidence mentioned above?

IV. If the petroleum deposits were coastal marine formations, deposited in shallow bays of the sea, they would be found under geographical alignments entirely different from the straight oil belts *in which they are actually being found.* The oil belts are evidently connected with the tectonic and orogenic disturbances of each region, and not with the ancient shore lines of the different formations. Moreover, along the same belt we find the petroleums impregnating sands of many different ages. In California, for instance, from and including the crystalline rocks to the Quaternary, there is a thickness of some 30,000 ft. in which productive sands are found. Yet, outside of the productive narrow belts along the Coast Range these 30,000 ft. of strata are barren of petroleum. Surely it cannot be imagined that marine bays of the ancient seas could align themselves in that way along fault lines or straight disturbed zones, and juxtapose themselves, one on top of the other, in formations of so many different ages, according to just the same tectonic zones of disturbance.

V. In shallow bays of the sea, in which sands are deposited, the organic matter is generally observed to have totally disappeared, having been destroyed by the oxygen of the air. Dr. v. Höfer admits this (p. 490); but he speaks of vague special favoring conditions which *occasionally* permitted the preservation and entombment of the organic matter. Would such special favoring conditions explain the enormous quantities of petroleums in the world? And why should these special favoring conditions occur at repeated periods during long ages in the same district along fault lines or disturbed zones; and what are these special conditions, anyhow? If petroleums were deposited in shallow bays, what about the deep vertical chimneys of Texas and Louisiana with several thousand feet of thickness of salt impregnated with petroleums?

VI. Admitting, for the sake of argument, that the soft organic

tissues of animals, or the fatty tissues of plants, were occasionally entombed, how did the transformation of these into petroleums take place? Dr. v. Höfer says it was by the action of long time, which permitted a slow distillation at low temperature; and, strange to say, as a synthetic proof of that proposition he gives the experiments of Engler, in which oils similar to petroleums were produced from organic fats by heating in a retort at temperatures from 300° to 400° C.—experiments made under conditions of temperatures entirely different from those which obtain in nature, and therefore not in the least to the point. If long time distilled some of the organic matter of the sediments into petroleums, how is it that it did not produce any other effect on these sediments, and on the "coals" contained in them, which are unaltered and undistilled? And if long time could replace temperature in bringing about distillation, should not everything on this earth be in a gaseous state, as there has been all the time imaginable in the eternity behind us to bring about the same effect as the highest imaginable temperature? Phenomena of physical or chemical changes of state in elements require certain temperature points and will not take place at a lower temperature, no matter the length of time. One might as well say that by leaving a turkey long enough in cold storage it would cook itself!

I will now take up in their order Dr. v. Höfer's criticisms of my proofs as contained in his paper.

1. I, of course, never intended to state anywhere in my papers that there was no methane in petroleums; what I did say was, that the marsh gas formed from the decomposition of plants is quite apart and different genetically from the methane of petroleums.

2. Whether the crystalline schists or gneiss, from which a very light gravity oil is produced near Newhall, Los Angeles county, Cal., is a metamorphosed sedimentary or not, and is of Jurassic age or of Archean age, makes absolutely no difference in the point which I raised about this occurrence of petroleum, namely, that the petroleum is found in crystalline rocks and therefore cannot possibly be indigenous, and must come from the San Gabriel granite or the magma below. If these crystallines are ancient sediments, they must certainly have lost all their organic matter during the metamorphosis, and especially such light gravity oil as is found there must have an extraneous origin. To attribute that origin to the neighboring Tertiary oil field is altogether impossible; since light oils of that nature, full of gas, never go down in the strata but always ascend.

3. To suppose that the oil and bitumen in the quicksilver deposits of California and elsewhere may have been extracted and transported from deeper bituminous rocks by the ascending ore-bearing solutions, is to reverse the problem without the shadow of a proof. One might as well suppose that the quicksilver itself in these veins had its origin in the

wall rocks, instead of the ascending ore-bearing solutions. It is well known to mining geologists that ore-bearing solutions, circulating in veins and fissures, sometimes impregnate the wall rocks and become diffuse in them; but they cannot do the reverse, and receive their contents from these wall rocks.

4. I must differ entirely with Dr. v. Höfer when he says that the occurrences of bitumen, petroleums, or graphite in metalliferous veins, pegmatite dikes, or volcanic rocks, are scanty or sporadic occurrences. I maintain, on the contrary, that they are frequent all over the world and constitute positive and overwhelming proofs that these products, in all such cases, have an inorganic origin. To suppose that volcanic or eruptive rocks can distill and absorb into their own mass petroleums or natural gas from bituminous materials in the wall rocks, is again to reverse the question without the semblance of a proof, and moreover, involves an impossibility. One cannot look for distillates inside of the hot mass which produces the distillation. The very word "distill" means "driving away."

5. The occurrence of oil around volcanic necks in Mexico is questioned by Dr. v. Höfer, who says that it is widely distributed. From all the records of reputable geologists who have examined the occurrences of oil in that country, and even from the records of Mr. Villarello, quoted by Dr. Höfer (p. 487), it is quite clear that the petroleum deposits are always intimately connected with the volcanic necks. In fact, this is one of the clearest evidences in the world of the solfataric volcanic origin of oil in enormous quantities.

6. Dr. v. Höfer says that, as a logical consequence of my views, deposits of petroleums should always be found in the vicinity of volcanic eruptions. As we have just seen, when it is found in such vicinity in enormous quantities, as in Mexico, the proximity and connection of the volcanics and the petroleums are denied. But when the volcanics are not plainly to be seen, then their occurrence in the petroleum fields is demanded. Faulting and fissuring connected with volcanic manifestations take place all over the world, not only in mountainous regions but also in regions of plains, and may be, and are, often accompanied with solfataric emanations, though the lava or volcanic rocks themselves do not appear at the surface. It is clear upon careful consideration of these phenomena that any belt of country very rich in eruptives, such as the "inner bend" of the Carpathians cited by Dr. v. Höfer, might be too much faulted and fissured to permit the storage of the gaseous emanations in the greatly disturbed and broken surrounding sediments, while another belt of the same country such as the "outer bend," which is sufficiently fissured to permit pent-up vapors and gases to force their way through to the porous portions of the sediments, and yet not so much as to permit their complete escape to the surface, would naturally

furnish the best and richest petroleum fields. Even in such oil fields as those of Pennsylvania and northwestern Ohio, where the strata are apparently undisturbed, we find such well-marked breaks as the Eureka-Volcano break and the grahamite vein of solid petroleum near Cairo, in West Virginia, and the famous Findlay break in northwestern Ohio, so well described in several of Orton's reports as the most pronounced disturbance in that State. In the greatest number of oil fields, the elongation of the different pools or fields, all in one direction, clearly demonstrates that they are connected with fissuring and faulting.

I believe it is unnecessary to prolong this discussion and to take up Dr. v. Höfer's remarks on the objections advanced by me in my paper, Petroleums and Coals, to the theory of organic origin, as I consider that these objections still stand and have not been sufficiently answered. Most of these points are also covered by my remarks in this discussion, or in my new paper, read at the same meeting of the Institute with Dr. v. Hofer's, and written before I had seen the latter.

Prof. Dr. H. von Hofer (communication to the Secretary*, translated by R. W. Raymond).—The remarks of Captain Lucas, the Chairman of the Committee, are highly interesting for the geologist and the miner of saline deposits; yet none of the facts he mentions can be regarded as evidences of the volcanic origin of petroleum. The emanation of gas from salt deposits has long been known, as Mr. Washburne, in the present discussion, has already observed. At various places, in Galicia (Wieliczka); in the Alps (Hallstadt); and in the German potash district (the Desdemona mine near Ahlfeld), natural gases in salt deposits have been the cause of gas explosions. In the salt mine of Szlatina, Hungary, natural gas was encountered in 1783, and used for several years to light the workings. The natural gas occurring in connection with the salt deposits in the Chinese province of Sz'tschwan served for centuries as a source of heat.

Petroleum also is found in salt, though mostly only as an impregnation, or in pockets, in the Carpathians and the salt deposits of northern Germany. In the latter, it has occurred sometimes in considerable quantity. For instance, oil to the value of 35,000 marks was obtained last year from an intrusion of petroleum into the Hope salt mine, near Schwarnsteck. Yet, at the present time rock salt and potash salt, without any admixture of oil, are won at this mine.″

At all the European localities above named, there is no trace of volcanic activity, and no plausible ground for inferring it.

During the Third International Petroleum Congress, held in 1903 at Burcharest, I first proposed, as generally applicable to deposits of pe-

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* Received Apr. 18, 1914.

″ *Petroleum*, Berlin, vol. ix, p. 981 (1914).

troleum and natural gas, the "dome theory," which has since received manifold confirmation, and has proved highly useful in practice. I was able at that time to support my new theory with facts observed in three continents, and showing without exception the favorable influence of the dome-shaped structural form. Most of these cases could be referred to one type—that of a locally elevated anticline. The salt domes of Louisiana and Texas constitute a class by themselves. The cause of their genesis has remained unknown hitherto, and will be difficult to discover, so long as the salt deposits have not been explored outside as well as inside of the domes. Captain Lucas assumes a laccolite, which has elevated the dome; but of this he has no evidence to offer. If a volcanic laccolite, as such, were the source of the oil formation, we would naturally expect the occurrence of petroleum likewise in connection with other laccolites, such as those of Utah, Colorado, New Mexico, Dakota, etc. But nothing of this kind is known, so far as I am aware. In fact, I think that nothing at all is yet known, as to origin of these salt domes. I can only refer to the "Ekzem-hypothesis," which is becoming more and more popular in Europe, as stating the simplest way in which, under the influence, perhaps, of other abnormal genetic conditions, these domes may have been formed.

The Knapp boring proved conclusively in the dome the regular saline series; first (at the bottom) lime; then gypsum; and then rock salt—as it occurs in all such *stratified* saline deposits. Hence it is impossible to conceive a volcanic process for the formation of the salt deposit.

The solid and tough rock reported at the bottom of the abandoned bore hole was never determined, and can therefore furnish no basis for a hypothesis. Perhaps it may have been, not even a rock, but a piece of iron which had fallen into the hole.

I am sorry that I must answer my friend, Captain Lucas, by saying that I cannot change my mind according to his suggestion.

From Mr. Coste I expected a more detailed reply, dealing, point by point, with my criticisms. But he has but a few things for remark.

Regarding his comments, I would observe that in a genetic question it is not a matter of indifference whether a given gneiss is, in Rosenbusch's sense, an orthogneiss or a paragneiss; that is, whether it was formed from granite, or from a post-Archæan sedimentary rock. Mr. Coste, for the benefit of his volcanic hypothesis, makes the California gneiss granitic, whereas it is evidently sedimentary in origin, and can therefore furnish no evidence of the volcanic origin of petroleum.

The origin of the petroleum found in the quicksilver deposits of California, I leave, as I have already said, to be discussed by my American colleagues. I could say it came from some oil deposit not far below the place which it now occupies, with as much reason as Mr. Coste has for

saying it came from great "volcanic" depth. One ignorant opinion would simply contradict the other.

It is notorious that in Mexico extensive oil fields are now known, which are far from any volcanic eruptives.

The various attacks of Mr. Coste upon the theory of the organic origin of petroleum and natural gas, I leave unanswered, until he shall have kindly offered a thorough and coherent criticism of my arguments, such as I made in the interest of science, concerning his.

Rock Disturbances Theory of Petroleum Emanations vs. the Anticlinal or Structural Theory of Petroleum Accumulations

BY EUGENE COSTE, CALGARY, ALBERTA, CANADA

(New York Meeting, February, 1914)

ALTHOUGH some of the observers who first paid especial attention to the occurrences of oil and gas in the strata (such as Hunt in 1859, Andrews in 1861, Winchell in 1865, Mendelejeff in 1876, Höfer in 1876, Minshall in 1881, and I. C. White in 1883) seem to have been impressed with the fact that oil and gas deposits were connected with the disturbances in the rocks caused by their upheaval,[1] yet, with the exception of Mendelejeff, and possibly Andrews, these observers do not appear to have understood what is really the one essential factor in the occurrence of oil and gas in the strata: viz., the faulting, uplifting, fracturing, fissuring, and jointing always accompanying even slight rock disturbances, and in certain districts (petroliferous provinces)[2] allowing solfataric hydrocarbon emanations to force their way up from the interior and to reach and impregnate the porous portions of sediments subjected to the disturbances. Instead of this simple explanation to account for the observed connection between petroleum deposits and rock disturbances, most of the observers mentioned above, and many others who have followed them on the same lines since, have entirely reversed the problem. To them, instead of the dissemination of gases from fissures into the sediments, it presented the accumulation and concentration, according to anticlinal or other geologic structures, of oil and gas originally present throughout the whole mass of the strata where they were produced by the decomposition or distillation of organic remains.

Whether this important problem involves accumulation from sources within the strata themselves, or infiltration and dissemination from outside sources, may be easily determined if all preconceived ideas are put aside and the established facts only are considered.

Physical Facts

Sedimentary strata are composed of alternate beds of shales, sandstones, and limestones, most of which are sufficiently close-grained to

[1] *West Virginia Geological Survey*, vol. 1A, pp. 49 to 53 (1904).

[2] Petroleums and Coals, *Journal of the Canadian Mining Institute*, vol. xii, pp. 273 to 301 (1909).

have retained from the time of their deposition enough water, held in their minute pores by capillary action, to fill all the spaces between their grains and render them entirely impervious to other fluids. Shales or consolidated clays form the bulk of the sediments and are especially fine-grained saturated impervious rocks, but many beds of sandstone or limestone are also quite impervious. Carll, Lesley, White, and Orton have often referred in their reports[3] to the wonderful impermeability of the sedimentary strata of the oil regions. A sufficient proof is the very strong natural gas pressures always recorded in the gas and oil deposits, and the great differences in the pressure of the gas of different sands tapped at various depths in the same well, or in nearby wells in the same pool or field. These strong pressures and wide differences in pressure have been noted in thousands of wells drilled in the 10,000 or 12,000 ft. of sedimentary strata along the Appalachian oil belt, for instance, from New York State through Pennsylvania, West Virginia, Ohio, and Kentucky to Tennessee.

In order to explain the retention of this gas under strong pressures (up to 1,500 lb. per square inch in some cases) in so many thousands of separate spots and at depths sometimes as shallow as 100 ft. and varying from that to 4,000 ft., we must certainly conclude that the sedimentaries forming the substrata of this vast region and ranging through many geological ages are remarkably impervious. It is for this reason alone that the petroleum deposits have not escaped to the surface, and have been preserved in a multitude of separate pockets, pools, or fields, with different pressures, though often quite close to one another and always comparatively near the surface. Yet without an iota of evidence we are asked to admit the reverse of what we see everywhere to be the case; and we are told by the advocates of the anticlinal theory that these impervious rocks which confine the gas and oil in their present reservoirs are themselves the source from which these substances were obtained. If it is impossible for the natural gas, notwithstanding its strong pressure, to traverse the 100 ft.—or the 3,000 or 4,000 ft. at the most—which separate it from the surface, it is still more clearly impossible that it could have accumulated, according to the anticlinal theory, by traveling miles through the same surrounding rocks to its present reservoirs, from supposed minute organic sources distributed throughout the very same impervious sediments.

In every oil and gas district a number of different sands are known to be productive, and along the Appalachian belt, for instance, dozens and dozens of different oil and gas sands have been largely productive, and they occupy in the geological scale an interval of 10,000 to 12,000 ft. from the Pittsburg coal of the Carboniferous down to the Potsdam sandstone of

[3] *Pennsylvania Geological Survey Reports*, 1885, p. 665; 1890, pp. 12, 13. *West Virginia Geological Survey*, vol. 1A, p. 63 (1904). *Bulletin of the Geological Society of America*, vol. ix, pp. 95, 96 (1897).

the Cambrian. According to the anticlinal theory the shales or other strata above any one of these sands form the impervious cover which retains the gas and oil in that sand and yet these same strata are also the prolific source of the oil and gas in the sand, or sands, above. Can anything be more illogical and more incomprehensible? Either the shales and other strata between these numerous oil and gas sands are impervious and therefore not the source of these products, or they are not impervious and these products could not then possibly have been retained in the sediments, as their upward movements through the strata would not have been stopped and they would have continued to penetrate through the pores of all sediments until they escaped to the surface. Every geologist will acknowledge that there is absolutely no difference in the degree of porosity of the beds of shale lying either above or below the productive sands whether they are made by the anticlinal theory to serve as an impervious cover or as a prolific source. But at any rate the one bed of shale between two productive sands cannot be made to perform two diametrically opposite functions, namely, impenetrable cover for the productive sand below and productive source for the oil and gas sand above.

Again, if, as required by the anticlinal theory of oil and gas accumulation from within the sediments themselves, these products could circulate freely through the minute pores and mass of the shales, such a movement could and would have commenced immediately after the deposition of the sediments, while they were still lying flat and undisturbed. It is entirely superfluous to assert that the upward movements of the petroleums in the sediments were started by a slight folding of the rocks, either in the form of an anticline or any other form, "by which the oil, gas and water may have been separated out and the oil concentrated in one locality."[4] The supposed organic petroleum products if they could move freely through the sediments, whether from the action of gravity, hydraulic pressure, or any other cause, would certainly start up toward the surface as soon as formed; they would never stop until reaching it; and therefore there would be no oil or gas at all found in the sediments to-day. In the Californian fields, Madill, Wheeler and other fields in Oklahoma, the Athabasca region of Canada, and many others, the productive sands are in unconformable formations, and sometimes right above the unconformities. To suppose that in these cases the petroleum in the lower bed of the Cretaceous, for instance (Dakota sandstone in Canada, or Trinity sandstone at Madill), is derived from the unconformable Paleozoic rocks underneath, is to ignore the long lapse of time between Paleozoic and Cretaceous times, which was certainly sufficient to exhaust out of the Paleozoic into the air, long before the deposition of the Cretaceous beds, all petroleum products formed from the decomposition of Paleozoic organic remains. If several unconformable formations (and in California there are at least three or four marked

[4] F. G. Clapp: *Economic Geology*, vol. vii, No. 4, p. 380 (June, 1912).

unconformities between different productive sands) contain petroleums in the same district and none at all in other districts with the very same sequence of formations, it must be due to some source for the petroleums outside of all these sediments, and to some infiltration, at a period more recent than the youngest productive formation, from a source beneath the oldest.

In all cases, therefore, the anticlinal theory of petroleum accumulations from sources within the sediments themselves fails to explain how the petroleums could possibly enter the porous portions of the sands, and remain there, and not continue their migration to the surface. On the contrary, solfataric petroleum emanations, through the agency of rock disturbances and fissuring, may enter and be retained in a patch of porous sands entirely surrounded by impervious rocks and there separate their component hydrocarbons, and associated gases and vapors, more or less according to gravity, the gas working its way to the higher parts of the porous sands, the water, if any, remaining in the lower parts, and the oil floating on the water, between it and the gas. In dry sands, such as the deep sands of Pennsylvania and West Virginia, the oil will naturally work down more or less to the lower part of the porous portions impregnated and will often be found in synclines. That part of the anticlinal theory which provides for a certain amount of separation of the water and of the different petroleums once they have reached a porous reservoir, is, of course, true. But even this has been much exaggerated; since the sand reservoirs in the oil and gas fields are very irregularly porous, and far from forming ideal tanks like a bottle or a room. Many impervious streaks or patches of various forms are found in the very heart of their porous portions, and they are seldom continuously porous over large areas. During the periods of disturbance there was also much fissuring and jointing; and, under the strong pressures of the gas always present in the petroleum emanations, these irregular tanks could not be filled up in the theoretical manner mentioned above. Every day, in the drilling of wells this theoretical arrangement of gas first, in the higher portions of the reservoirs, then oil and then water, is entirely reversed. Every day, dry holes or oil wells or salt-water wells are "drilled in" on the top of the anticlines while large gas wells are obtained away down on the slopes or at the bottom of synclines. On the other hand, many anticlines are barren of petroleums, although these anticlines are developed in sedimentary formations where every requisite condition demanded by the anticlinal theory is absolutely fulfilled: namely, fossiliferous strata; porous arched reservoirs; impervious covers; and water in the porous rocks; but where the essential factor is missing: namely, the rock disturbance producing the necessary fissure through which the solfataric hydrocarbon emanations could force their way up to the porous reservoirs.

The structure of many an oil or gas field has no resemblance to an anticlinal structure. A. Beeby Thompson in a paper[5] read before the Institution of Mining and Metallurgy of London, England, in which he reviews the relationship of structure to the occurrence of petroleum, graphically illustrates by many good sections the great diversity of oil and gas field structures and thus plainly demonstrates the reverse of what he advances in the text: namely, that oil and gas fields are generally connected with anticlines and that "an anticlinal structure favors the accumulation of oil"[6] and "played a most important part in the formation of oil fields."[7] Indeed, a number of prolific and prominent oil fields are shown by Mr. Thompson's diagrams to exist in strata presenting structural conditions entirely different from anticlines. Other instances and examples to show that oil and gas fields are found under all sorts of structural conditions have been often furnished by other writers in their studies of the different oil fields of the world, especially of America. It has been found necessary really to transform the anticlinal theory by expanding it into a structural theory including all sorts of other forms. This structural theory was elaborated by F. G. Clapp in his papers in *Economic Geology* (vol. v, No. 6, *Sept.*, 1910, pp. 503 to 521, and vol. vii, No. 4, June, 1912, pp. 364 to 381). What the author principally proves from his classification of oil and gas fields is really that petroleum deposits are not dependent on or controlled by any kind of structure whatever. Such deposits are found, according to this classification: (1) on strong anticlines standing alone; (2) on well-defined alternating anticlines and synclines; (3) on monoclines with change in rate of dip; (4) on structural terraces; (5) on broad geanticlinal folds; (6) on bulged anticlinals; (7) in saline domes; (8) around volcanic rocks; (9) along sealed faults; (10) sealed in by asphaltic deposits; (11) at contact of sedimentary and crystalline rocks; (12) in joint cracks of sedimentary rocks; and (13) in crystalline rocks. To these classes of deposits may be added the following: (14) on gentle slopes or monoclines without any change in the rate of dip, as the Welland field, Ontario, the Madill field in Oklahoma, etc.; (15) in vertical veins cutting across the strata, such as the gilsonite veins in Utah, the albertite vein in New Brunswick, Canada, and the grahamite vein near Cairo, West Va.; (16) in quicksilver and other metallic veins; (17) in and along volcanic or igneous dikes; (18) in meteorites;[8] (19) in the volcanic emanations of to-day; and (20) in synclines.

With so many different classes of petroleum deposits, it is clear

[5] *Transactions of the Institution of Mining and Metallurgy*, vol. xx, pp. 215 to 237 (1910–11).

[6] *Bulletin* No. 77, *Institution of Mining and Metallurgy*, p. 2 (Feb. 15, 1911).

[7] *Idem*, No. 78, p. 4 (Mar. 15, 1911).

[8] *Bulletin* No. 330, *U. S. Geological Survey*, p. 632. (1908).

that the structure in itself is not the controlling factor and that too much weight has been attached to the structure or folding of the sediments surrounding the petroleum deposits. In order to make the anticlinal theory fit everywhere unwarranted new names have been given and supernatural properties have been attributed to certain structures (such as "arrested anticlines" and "quaquaversal domes") which in no possible way could of themselves affect the oil or gas accumulations.

Even along the Appalachian oil belt, which is supposed to give many typical examples of anticlinal structures, it is well known that the oil and gas fields are really in the bottom of a deep geo-syncline between the Cincinnati anticline and the Appalachian uplift. These so-called anticlines, on which the oil and gas fields have been developed in that region, are mere wrinkles of small amplitude in the bottom of that deep geo-syncline. The height of each wrinkle is only a few hundred feet at the most, and therefore (if the sands were continuously porous, and the strata in general were as permeable as the anticlinal theory requires to explain the accumulation of the large quantities of petroleums obtained), the oil and the gas would not have stopped on or near the summit or arch of these wrinkles of porous sands, but, if the covers of these sands were impervious, would have traveled along the sands from one arch to the other and gradually up the western or the northern slope of the geo-syncline until reaching the surface at the outcrops of the sands in Ohio, or northern Pennsylvania and New York State. Many differences in pressure have been noted between the gas found on one of the wrinkles and that in the same sand on the adjoining one. The few hundred feet of water in the syncline between these two wrinkles could not possibly prevent the gas from traveling from one to the other and equalizing that pressure, and, as I have said above, could not possibly prevent the gas from getting out up the slopes of the geo-syncline to the outcrops.

In the Gulf oil fields of Louisiana and Texas, it is still more clearly evident that the particular shape or structure of the salines or mounds was not a factor in the accumulation of oil from the surrounding sediments. These salines cover indeed such small areas that it is only a stretch of the imagination to suppose that the enormous quantities of oil obtained from under them could possibly be derived from the strata affected by what has been called the "quaquaversal doming" under the salines. Moreover, this doming does not extend to the Tertiary or Cretaceous clays and sands surrounding the salines or mounds; and therefore this particular structure could not be a determining factor of oil accumulations from the surrounding sediments. On the contrary, it is well established that the sediments under the salines have been replaced by masses of salt, limestone, dolomite, silica, sulphur, and gypsum, of secondary origin from solutions moving vertically and carrying hot oils, hot water, and hydrocarbon and sulphur gases, and that these products did not extend horizontally into the im-

pervious sediments surrounding the chimney-like channels under the salines; also, that these salines are distributed along lines of deep faults which were evidently the first channels for emanations of the hydrocarbons and other vapors and waters, before they finally came out to, or near, the surface through the chimneys under the salines. What has structure to do with occurrences of oils in deposits of this kind, which are clearly due to the rock disturbance under the salines, and to hot gas-aqueous emanations coming up from below? This explains the fact that oil in large quantities is "struck" at many different levels under the salines, and none is struck, outside of the salines, in the surrounding sediments.

That these are solfataric volcanic emanations is made plain by the occurrences of oil a little further south, along the same coastal plain, in Mexico. There one can actually observe numerous volcanic necks of olivine basalt, scattered at wide intervals, and also distributed along fault lines similar to the lines connecting the salines of Texas and Louisiana; and these volcanic necks are surrounded by large seepages of asphalt and the very prolific oil fields of this region are all developed in close proximity, around these volcanic necks. F. G. Clapp in a paper in *Economic Geology* (vol. vii, No. 4, June, 1912) says with regard to this class of oil deposits in Mexico:

"In close proximity to the basaltic upheavals, the Tamasopo limestone and overlying formations have been domed upward, forming pockets or places of change in rate of dip at the base of the upheavals and surrounding them, where large deposits of oil have accumulated.

It is known, however, that these Mexican lava cores form really vertical pipes, which may be said to have drilled themselves upward through undisturbed and almost horizontal strata of shales, limestones, and sandstones.[9] and Mr. Clapp himself admits that in his hypothetical cross-section of one of the Mexican oil fields.[10] The supposed action of the doming referred to by Mr. Clapp would therefore have been so infinitesimal as to be entirely negligible in considering the accumulations of oil out of the surrounding sediments. According to Mr. Clapp's theory the Cretaceous sediments surrounding the lava cones of Mexico tenaciously held back in their pores, during long ages, enormous quantities of petroleum products, until such time as the volcanic peaks and needles pierced through them in late Tertiary times. In doing so the volcanic cores tilted only very slightly the sediments immediately surrounding them. It would be impossible for this slight tilting of very small portions of the whole mass of the strata of this region to effect the immediate release from

[9] *Mining and Scientific Review*, Aug. 24, 1907, pp. 247, 248. *Journal of the Canadian Mining Institute*, vol. xii, p. 281 (1909).

[10] *Economic Geology*, vol. vii, No. 4, Fig. 58, p. 378 (June, 1912).

these sediments of the enormous quantities of oil supposed to have been so firmly held by them during long periods; and it can only be concluded that the effect of structure in this case at least has evidently been much overdrawn. Why should so much be demanded from poor impotent structure alone, when it is manifest that these Mexican petroleum deposits are directly connected with vulcanism, and due to solfataric volcanic emanations accompanying the upheavals of the basaltic cones?

Many other instances to show that structure is not a determining factor in the migration and accumulation of oil in the California fields may be found in the reports of Arnold, Anderson and Johnson. These authors summed up their conclusions as follows:[11]

> "This migratory faculty may be ascribed entirely to the presence of the associated gas which would cause the oil to fill every crevice offering a point of escape or a point of lodgment."
>
> "The condition of the rocks is the chief factor that controls the matter of where the oil is stored most abundantly."
>
> In California, "many of the 'oil sands' so called, are not true sands, but zones of fractured shale or flint offering interspaces in which the oil can gather."
>
> "Large accumulations in anticlines may be accounted for primarily by the cavities offered by the strata along upward folds, and secondarily by the presence of less pervious beds arching over such folds and affording favorable conditions for the confinement of oil and gas tending to escape."

If to these conclusions is added the consideration of the many strong faults and disturbances always plainly in evidence in the fields of California, and also the consideration of the fact that in these fields a number of unconformable formations, from and including the crystalline gneisses to the Quaternary, are productive of oil, it will be readily understood that the migration of oil is effected vertically along fissures and from a source beneath the crystalline gneisses instead of horizontally and more or less under the determining influence of the structure.

The same conclusion has been reached by Washburne in the Florence field of Colorado: viz., that geologic structure has had little or no influence on the movement or the accumulation of oil which is present mostly in open fissures in a zone of shales 2,500 ft. thick, at the bottom of a syncline.

Geologic Facts

Simple and well-known geological conditions and considerations prove just as conclusively that the occurrences of oil and gas in the strata can only be attributed to a process of infiltration, dissemination, and impregnation of the porous portions of the sediments from deep solfataric volcanic

[11] M. R. Campbell: *Economic Geology*, vol. vi, No. 4, pp. 387, 388 (Juen, 1911).

sources. As I have already on several other occasions[12] presented in detail a number of facts and arguments in support of these views, I will here only recapitulate the principal points as briefly as possible:

1. In the solfataric volcanic phenomena enormous quantities of hydrocarbon gases and vapors are constantly thrown out in the air in all the volcanic districts of the world. See my previous papers and Dr. G. F. Becker, *Bulletin No.* 401, *U. S. Geological Survey*, for short reviews of this evidence, which, however, will be found at length in the writings of the eminent geologists and chemists who have made special original studies on this subject, notably, Elie de Beaumont, Humboldt, De Lapparent, Suess, Fouqué, Le Blanc, Silvestri, Stocklassa, Brun, Charles Sainte-Claire Deville, Lacroix, Gauthier, Tschermak, Janssen, Libbey and Sokolow. A. Gauthier, for instance, has shown not only that hydrocarbons and other combustible gases are to be found in the lavas or volcanic rocks of to-day, or associated with these rocks in their eruptions, but that enormous quantities of these combustible gases are contained also in ancient igneous rocks, and that by simply warming these rocks to a moderate red heat he could extract from them at least 100 times their volume of mixture of combustible gases and water vapor.

After giving the details of his experiments and analyses he says[13]

"Putting aside the reactions pertaining in the melted portion of the interior of the globe, if we consider what happens when certain already crystallized masses of the crust are reheated to red heat on account of their sinking internally, or because lateral pressures of different parts of the crust cause an uplift of the melted rocks from the interior along the points of minimum resistance. When these rocks already solidified once are thus reheated by the incandescent masses it will be seen that they will be bound to give off by all possible vents the gases and vapors produced in the experiments just cited and recorded. From these, as we have seen, one liter of granite gave (at 1,000° and calculated only for this temperature) about 20 liters of various gases and 89 liters of water vapor, that is to say, more than one hundred times its volume of gases. One can understand from this the great explosive force due to these reactions, and that it is not at all necessary to admit the hypothesis of the penetration of superficial or meteoric waters down to the igneous masses as a necessary condition to the production of volcanic phenomena. . . . One will understand that to explain the origin of the water in volcanoes, the nature of the gases emanated and the violence of the eruptive phenomena, that it is sufficient for the deep crystalline strata to be reheated only a few hundred degrees, and the emanation of volcanic gases with their composition (combustible gases) and their formidable pressures, will be the necessary result of this reheating."

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[12] Natural Gas in Ontario, *Journal of the Canadian Mining Institute*, vol. iii, pp. 68 to 89 (1900). The Volcanic Origin of Natural Gas and Petroleum, *Journal of the Canadian Mining Institute*, vol. vi, pp. 73 to 123 (1903). Petroleum and Coals, *Journal of the Canadian Mining Institute*, vol. xii, pp. 273 to 301 (1909). The Volcanic Origin of Oil, Trans., xxxv, 288 to 297 (1904). Fallacies in the Theory of the Organic Origin of Petroleum, *Transactions of the Institution of Mining and Metallurgy*, vol. xxi, pp. 91 to 192 (1911–12).

[13] *Comptes Rendus de l'Académie des Sciences*, 1901 to 1903.

Dr. Albert Brun in his *Recherches sur l'Exhalaison Volcanique* gives many interesting analyses of the gases found in volcanic rocks, and given off at volcanic or explosive temperatures, that is to say, above 600° or 800° C., which he recognizes as the only true volcanic gases. These analyses show that hydrocarbons are frequent in volcanic rocks all over the earth and that they are sometimes quite abundant. For instance, in an obsidian from the Plomb du Cantal, France:

"The analysis showed that the vapor which is distilled is slightly ammoniacal and carries much bitumen. Heated in the vacuum its fused, vitreous residue is perfectly black with carbon. Moreover, there is enough bitumen present to form on the cold parts of the apparatus oily striations. These oils are soluble in chloroform, with a brown fluorescence, and are combustible with a clear flame."

Many other analyses of lava, obsidian, and other volcanic rocks are stated by Dr. Brun to have given from traces of hydrocarbon to quantities even more abundant than in the instance cited above, and out of 67 analyses 38, or 57 per cent., gave hydrocarbons.[14] The volcanic rocks containing the petroleums were from widely distributed localities, such as Mt. Erebus (antarctic), Armenia, Abyssinia, Java, Japan, Peru, Tamanfaya, Canaries, Iceland, Milo, Vesuvius, Stromboli, Etna, Arran Islands, Scotland, Sweden, Germany, Hungary, Italy and France.

In view of these and other evidences, no geologist can to-day deny that petroleums are now proved to be abundantly produced in the phenomena of vulcanism, whether recent or ancient.

2. There are no geological phenomena of to-day or of ages past in which, through organic agencies, petroleums—that is to say, the mixtures of hydrocarbons known as petroleums—are being produced, or are known to have been produced. The gradual decomposition of entombed vegetable organic matter in nature to-day, and during the past geological ages, is and has been accomplished in the sedimentary strata at low temperatures and has resulted in the formation of peat, lignite, coal, and anthracite; that is to say, in the formation of oxygenated fixed carbon compounds very different from petroleums. If these "coals" had been distilled it might be argued that "petroleums" were thus formed, but it is, of course, well known that as a general rule they have not been distilled: the necessary heat to bring about distillation was never attained in the unaltered sedimentary strata. At any rate, it is a matter of geological record that the "coals" are found everywhere in the sediments in the undistilled state and not as coke, and that coal and petroleum deposits have no genetic connection of any sort one with the other.

It is equally a matter of geological record that the soft tissues of animal organic matter were not finally entombed in the sediments, where they have left absolutely no trace of their former existence, as demonstrated

[14] *Economic Geology*, vol. vii, No. 1, pp. 7, 8, 9 (Jan. 1912).

by the billions of fossils in our paleontological museums and collections, and in the impervious rocks everywhere, without the slightest trace of any carbon compound to be found in them. The former animal organic matter of what is to-day the fossil animal world evidently decomposed fully, or otherwise disappeared entirely, before the final entombment of the hard part of the animal; and therefore no petroleums could possibly be formed from it.

It is insufficient to argue, against such evidence to the contrary, that petroleums must have an organic derivation, because the large petroleum deposits are always found "associated" with sedimentary strata and fossiliferous rocks. This word "associated" is very vague. It takes more than the presence of water in a cave or in a porous rock to prove that that water originated there. Are not volcanic rocks themselves thus "associated" with sedimentary strata—often in successive horizontal flows or laccolitic intrusions interbedded with sediments, or in veins and masses cutting across sediments? Are not the solid petroleums thus found in irregular veins or masses cutting across the sediments? Are not the liquid or gaseous petroleum deposits themselves local and irregular impregnated spots of the porous sediments, not at all in sheets like coal beds? In some districts (petroliferous provinces) they occur in many sands throughout all the sequence of the sediments from the earliest Cambrian to the latest Quaternary, entirely irrespective of the fossiliferous beds, and mostly in sharp sands without fossils—sometimes above great thicknesses of shale strata, sometimes below all shales, as, for instance, the petroleums in the Trenton limestone of Ohio and Indiana, while in other districts the same entire series of sediments is absolutely barren of petroleums.

It is also insufficient to say that because volcanic rocks are not everywhere to be seen in the petroliferous districts a solfataric volcanic origin cannot be attributed to the petroleums. As I have already quoted several times in other papers, De Launay in his *Science of Geology* remarks:

> "The dislocations of the earth are more and more observed to have taken place not alone in mountainous regions but even in regions of plains." . . .
>
> "All the regions of the earth, probably without exception, have been subjected to dynamic movements to which are connected igneous manifestations of internal origin."

These disturbances furnished the necessary fissuring of certain belts of strata, whether much disturbed and uplifted, as in California, Roumania, and Galicia, or sometimes lying still comparatively flat and apparently undisturbed, as along the Appalachian belt in Pennsylvania and West Virginia. In all cases, however, the imperviousness of the bulk of the strata, especially the shales, and the fact that these readily caved in and sealed the fissures, prevented the petroleums from entirely escaping to the surface. Through this fissuring of the strata the pent-up solfataric hydrocarbon emanations came up from the interior, losing some

of their pressure as they forced their way up through the fine minute fissuring and the imperfectly porous sands. Hence the differences of pressures recorded in the different sands of the same field and the higher pressures recorded in all fields as the petroleums are found in deeper and deeper sands. Hence the fact that in every field or district, not one but a number of different sands, belonging to a number of different geological formations, sometimes unconformable, are impregnated with the petroleums in irregular spots, here and there, along the structural lines of disturbances, while much larger areas of the same series of sediments in the neighboring districts are absolutely barren.

The distribution of the Mexican and of the Texas and Louisiana oil fields along lines of fault has already been referred to, as well as the evident connection of the oil of these fields with vulcanism.

Similarly the oil fields of California belong to much disturbed and fractured belts bordering the Coast Range on each side for many miles. There also the migratory ascent of the hydrocarbons through faults and fissures is most plainly attested by numerous asphalt veins, and by tar and gas springs. That these faults and disturbances, constantly referred to in the reports of Arnold and Anderson, have brought up the hydrocarbon emanations from below the crystalline gneisses and granite is evidenced by the fact that in Placerita canyon, 5 miles east of Newhall, Los Angeles county, a very light oil (between 50° and 60° B.) is produced from crystalline gneisses which overlie the San Gabriel granite.[15] Above these crystalline rocks, the oil is found in California to be stored in the porous reservoir-rocks, or in the seams and joints of any and all the strata affected by these profound disturbances in a geological column of some 26,000 ft. of Cretaceous, Tertiary, Fernando, and Quaternary sediments, those of each period lying unconformably on the next lower, and the lowest unconformably on the crystalline rocks. It cannot be imagined that the petroleums contained in any one of these rock series can have originated from organic remains in the underlying unconformable series, since they would have been lost at the surface, if they had migrated at all, during the long intervals marked by the unconformities, unless a still more improbable process be imagined: namely, that in each case the organic remains accommodatingly waited until the end of the long period marked by the uncomformity, before beginning to be decomposed and transformed into petroleums, and to migrate upward. There is only one possible explanation: solfataric volcanic emanations of hydrocarbons coming up from below the crystalline rocks along the fault lines and in the zones of disturbance, at repeated periods of dynamic movements of the Coast Range. Some of these movements must have been very recent to explain the oil in the gravels of the Quaternary and the large seepages often found at the surface.

[15] *Bulletin No.* 309, *U. S. Geological Survey*, pp. 100, 101 (1907).

If the other oil districts of America are considered broadly it will be seen that the Appalachian fields, the Northwestern Ohio and Western Ontario fields, the Illinois fields and some of the Indiana fields, and the Mid-Continent fields, all show linear distribution of their petroleum deposits more or less parallel to the Appalachian uplift, except some of the Oklahoma pools, which follow the direction of the Arbuckle or Wichita Mountain uplifts. Along these oil belts the numerous petroleum-bearing rocks do not represent fixed geological horizons—the oil and gas rising from various beds of different ages; and outside of these oil belts, structurally favorable folds are barren of petroleums in the same geological horizons.

Following the Appalachian oil belt, for instance, from Tennessee and West Virginia through Pennsylvania to New York State, the petroleums are found in lower and lower rocks in the geological scale, until they are found right on the top of the Archæan in the Potsdam sandstone. The Archæan, therefore, or the igneous magma below it, must be the final source. It would be puerile indeed to assume one hundred different sources in the sediments between the one hundred different productive sands of this oil belt, since it must then be assumed also that every member of the sedimentary series separating two oil-bearing sands is the impervious cover of the sand below it and cannot therefore be considered as the source of the petroleums in the sand above it; and since it has to be admitted, after all, that the Archæan rocks, or the igneous magma below the Potsdam, is one at least of the sources.

This peculiar occurrence of the petroleum deposits in the sedimentary strata of all ages, yet in certain districts only, along zones of tectonic structural disturbances of these strata, where they align themselves in "petroliferous provinces," as do the metals in "metallogenetic provinces," is exemplified not only in North America but all over the earth. In Russia the petroleum deposits follow the Caucasus uplift from the Tamansk peninsula in the northwest to the Apcheron peninsula in the southeast for a distance of 750 miles. In Galicia and Roumania they follow the Carpathian range and turn with it in a grand sweep of more than 500 miles from a northwest to southeast direction in Galicia to an east-and-west one in Roumania. The same association of naphtha to a dislocated zone along the Kurdestan chain in Persia, has been well described by J. de Morgan.[16] The Tertiary tectonic and igneous "girdles" around the Pacific and the Caribbean sea are followed by an immense Tertiary "petroliferous province," of which the oil fields of California, Alaska, Japan, Borneo, Sumatra, Java, New Zealand, Peru, Colombia, Venezuela, Trinidad, Mexico, and Texas are salient points.

The constant recurrence of hydrocarbons in volcanic and igneous rocks, volcanic emanations, metallic and other veins, meteorites, comets

[16] *Annales des Mines*, 9th ser., vol. i, pp. 227 to 238 (1892).

and other stellar bodies, clearly demonstrates that petroleums are inorganic. The hydrocarbon emanations sometimes follow closely the volcanic lava, as in the Mexican and other oil fields, but they need not be, and often are not, accompanied to the surface by volcanic rocks. They must, notwithstanding, everywhere be held to be of a solfataric volcanic nature, as shown by their peculiar position along the tectonic structural disturbances, and because, moreover, they could not originate in the mass of the impervious sediments, and could only travel through these by means of faults or fissures from deep sources. Besides, with their associated salt and sulphur they are identical with solfataric volcanic vapors emanating from all the volcanic districts of the earth, and are absolutely unlike anything else in nature known to be in the active process of formation at the present time. Like volcanic vapors these hydrocarbons are always found under high pressures, often giving rise to violent explosions and sudden outbursts in enormous quantities, after earthquake shocks, and along disturbed dynamic lines; and, like volcanic vapor, they are also found at times to be still hot and associated with hot waters.

Discussion

Hans von Höfer, Vienna, Austria (communication to the Secretary*).—I will confine my remarks at first to the question which I raised in my paper as to the volcanic origin of petroleum, following thus the order observed by Mr. Coste in his reply, which now lies before me.

1. Methane is always the same chemically, in whatever manner it may have originated.

2. To the geology of petroleum the age of the crystalline schists, whether gneiss or phyllite, is of the highest significance. The occurrence of oil as a primary deposit in a crystalline schist of Archæan age, would warrant the conclusion that it could not have an organic origin, since in that age no organisms existed. But this inference would not hold good as to oil from a crystalline schist of Jurassic age, like that of Newhall, Los Angeles county, Cal., since in that period abundant organic life inhabited the earth, and therefore such oil might have an organic origin. Hence the essential point in the present discussion is not the crystalline schist, but its geological age.

What the Newhall crystalline schists were originally, *i.e.*, immediately after their deposition, we do not know; but it is not impossible that they are the product of the metamorphosis of sand, or of sandstone, as is, for instance, very probable for many gneisses.

3. Concerning the source of bitumen in the quicksilver deposits of California, I spoke with reserve in my paper, leaving the question to my

* Received July 2, 1914.

American professional colleagues. I am now fortunately able to cite a recent American authority on that subject, namely, J. Allen Veatch, who says, in his very interesting paper on the The Genesis of the Mercury Deposits of the Pacific Coast:[18]

> "The theory that this oil originated from organic matter precipitated into the open fissure is supported by the fact that the Sierra dikes do not contain oil."

Mr. Coste's assumption that only such solutions as circulated exclusively in veins and fissures impregnated the wall rocks, and that the opposite course would be impossible, surprises me greatly; since we mining geologists have for more than half a century recognized this opposite course as lateral secretion.

4. On the strength of the personal observations of many years, as well as of the literature accessible to me, I can only repeat the declaration that gaseous, liquid, and solid bitumens occur in ore-bearing veins and eruptive dikes very seldom, and always in small quantity. I believe that I was one of the first to collect and publish the data concerning the occurrences of bitumen in ore deposits.[18] In that paper Mr. Coste will find more examples than he appears to be acquainted with. He assumes without proof that the bitumen found in eruptive dikes is of volcanic origin. I assume that the bitumen contained in the intrusive magma has come from bituminous or carboniferous strata, through breaks in which it ascended. The two hypotheses face each other, both lacking direct, positive proof. My explanation has been adopted very recently by W. W. Arschinow[19] for the occurrence of anthraxolite in the eruptives of the Crimea, and by Falkenberg,[20] for the bitumen found in the pyrite deposit of Lilleboe, Norway. As I have already observed, Mr. Veatch confirms it for the California quicksilver deposits.

The etymological argument based by Mr. Coste upon the relation between "distilling" and "driving away" escapes my apprehension.[21]

5. The significance of the volcanic necks of Mexico has long been clear. The primary oil deposits were elevated by these eruptions, and acquired thereby a dome-like form, which (as I demonstrated at the Petroleum Congress of 1903 in Bucharest) is peculiarly favorable to the accumulation of oil. The latest publication concerning the Mexican oil fields—

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[17] *Bulletin No.* 86, February, 1914, p. 225.

[18] In my Erdölstudien (Studies of Petroleum): See *Sitzungsberichte der k. Akademie der Wissenschaften, Wien, math. naturw. Klasse,* vol. iii, part 1.

[19] *Lithogaea,* G. 50, p. 15.

[20] *Zeitschrift für praktische Geologie,* vol. xxii, No. 3 pp. 141, 152 (Mar., 1914).

[21] TRANSLATOR'S NOTE.—Dr. Höfer apparently refers here to the actual derivation of "distil" from the Latin "stilla," a drop, and its primary meaning, "to fall, or (transitively) to let fall, in drops." The word, therefore, does not etymologically convey the notion of "driving away."—R. W. R.

that of the distinguished American expert, I. C. White,[22] confirming Villarello's view, establishes the organic origin of the oil, and shows also that primary deposits of it occur in the Cretaceous strata. Mr. White says:

> "There can be practically no doubt that the mother rock or main reservoir of petroleum along the Gulf coast of Mexico is the Tamasopa limestone of the Mexican Cretaceous terranes."

It is thus impossible to maintain that the occurrence of oil in Mexico furnishes "the clearest evidence in the world of the solfataric volcanic origin of oil in enormous quantities," as Mr. Coste declares. On the contrary, the organic origin of the Mexican oil is beyond doubt.

6. I object to Mr. Coste's volcanic hypothesis, that if it were true, then, as a logical consequence, oil ought always to be found in the neighborhood of volcanoes and deep faults and fissures, which is not the case. He answers this objection with a speculation concerning the Carpathian oil deposits, which seems to ignore the main point—namely, the occurrence of the volcanic rocks in the inner, oil-poor Carpathian circle—and to pursue only the notion of a possible difference in the formation of fissures on the two sides of the range. My knowledge of the Carpathians for 30 years past enables me to say positively that anticlines and fissures are found occurring in the same manner on both sides.

With regard to the conditions in Pennsylvania, and the occurrence of volcanoes far distant from any oil deposits, I would simply refer to what I said in my former contribution.

Let me now briefly consider the objections of Mr. Coste to the organic origin of petroleum. I number my paragraphs to correspond with his.

I. To the question, "Why is not this process in active operation in the world to-day?" I reply that during the last century immense accumulations of the dead bodies of marine or fresh-water animals have been repeatedly observed. In my book on Petroleum[23] I have given a brief summary, and in my Petroleum-Studies, already cited, a more detailed discussion of these accumulations. I may mention as an example the masses of dead fish in Florida, described by the celebrated American biologist, Agassiz, who said of them that such accumulations of corpses might very well form oil-bearing deposits. The actual development of petroleum from the soft parts of mollusks was observed by Bertels[24] in the Gnilaja Balka, on the north side of the Caucasus. Where are oil deposits formed to-day by active volcanoes? I would be grateful to Mr. Coste for a few instances.

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[22] *Bulletin of the Geological Society of America*, vol. xxiv, No. 2, p. 253 (June, 1913).

[23] *Das Erdöl und seine Verwandten*, 3d ed., pp. 256 to 260.

[24] *Erdöl und seine Verwendung*, p. 246.

II and III. In the formation of petroleum, as is usual in processes of decay, carbonic acid is generated, and when prevented from escaping, effects the solution of the calcareous molluscan shells, which accounts for the absence of such shells from oil deposits. Grzybowski studied the foraminiferæ accompanying the Carpathian oil deposits, and found the siliceous shells to occur frequently and in good preservation, while the calcareous shells were either altogether gone or present in scanty amount and corroded condition.

IV. There are in the world so many "tectonic and orogenic disturbances," like those in the oil regions, and yet without any oil. There must be first a primary deposit, and only afterward can such disturbances specially concentrate the oil in some places, excluding it from others. Mr. Coste apparently fails to make sufficient distinction between formation and accumulation.

V. The conditions under which organic material is preserved in bays are by no means vague. Not alone I, but also most petroleum geologists, have reached the conclusion that a petroleum deposit, if it is to be productive, must have clay, clay-slate, or similar material as a hanging-wall; that is to say, the buried organism must have been excluded as early as possible from the air, so that the change which takes place shall be, not destruction by oxidation, but that process of decay which plays a leading part in the formation of mineral oil. The air-tight roof hinders also the escape of the oil after it has been formed.

VI. That in chemical processes longer periods of time may take the place and produce the results of higher temperatures, is beyond doubt. I may be permitted to remark, in passing, that in the transformation of fatty organisms, a heat of reaction is developed, which still betrays itself in the small geothermic scale of the oil fields. The formation of coal likewise liberates heat; but that it proceeds differently from that of petroleum need cause no surprise, since its original material—plants, and particularly cellulose—is entirely different from the fats out of which petroleum is formed.

In defending the theory of the organic origin of petroleum, I have been necessarily brief. If Mr. Coste finds my statement inadequate, I beg him to study without prejudice the many pages of my books, in which I have given proofs of this theory, based upon nearly 40 years of study of the subject.

With this suggestion, I regard the present discussion as closed, believing that I have sufficiently shown Mr. Coste's position in favor of the volcanic origin of petroleum to be entirely untenable.

The Age and Manner of Formation of Petroleum Deposits

BY E. T. DUMBLE, HOUSTON, TEXAS

(New York Meeting, February, 1914)

PROF. EDWARD ORTON, in his *Report on the Occurrence of Petroleum, Natural Gas and Asphalt Rock in Western Kentucky,* thus clearly states his ideas of the universal dissemination and rare accumulations of the bitumens:[1]

"We need to bear in mind that the various members of the bituminous series are abundantly and almost universally distributed among the unaltered sedimentary rocks of the earth's crust. The valuable accumulations of these substances are rare, it is true, but one can scarcely go amiss of petroleum, asphalt or gas, at least in small quantities, among the stratified rocks that retain their original structure."

Speaking of the Ohio valley, he adds:

"A fifth of one per cent. of petroleum, if distributed through a thousand feet of rock, would make a total to the acre, or square mile far beyond any production that has ever been realized from the richest oil field, and percentages of this amount are not only not rare to find, but are even hard to miss."

Dr. F. W Clarke in his *Data of Geochemistry* (*Bulletin No.* 491, *U. S. Geological Survey,* 1911), discussing these views of Orton with similar views of T. Sterry Hunt and Szajnocha, says that they "lead to the conviction that the formation of bitumens is a general process and by no means exceptional. Wherever sediments are laid down, inclosing either animal or vegetable matter, there bitumens may be produced."[2]

The organic origin of the bitumens, including petroleum, has long been an accepted fact with nearly all geologists, but the method, place, and time of the transformation into petroleum or other bitumen is still under discussion.

Dr. Orton says:[3]

"The statements now presented. . . . . bring before us two main views as to the origin of petroleum, viz.:

"(1) Petroleum is produced by the primary decomposition of organic

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[1] P. 30. (Kentucky Geological Survey, 1891.)

[2] P. 703.

[3] P. 42.

matter, and mainly in the rocks that contained the organic matter. Of this view Hunt is one of the chief advocates.

"(2) Petroleum results from the distillation of organic hydrocarbons contained in the rocks, and has generally been transferred to strata higher than those in which it was formed. Newberry and Peckham have been quoted at length in support of this general theory. Newberry holds that a slow and constant distillation is in progress at low temperatures. Peckham refers the distillation of the petroleum of the great American fields to the heat connected with the elevation and metamorphism of the Appalachian mountain system."

Discussing the age of petroleum deposits, Dr. Orton says:[4]

"These three views, as to the date of the origin of petroleum and gas, are seen to cover almost all of the possibilities in regard to the subject. Hunt believes petroleum to have been produced at the time that the rocks that contain it were formed, once for all. Newberry believes it to have been in process of formation, slowly and constantly, since the strata were deposited. Peckham refers it to a definite but distant time in the past, but long subsequent to the formation of the petroliferous strata. He supposes it to have been stored in its subterranean reservoirs from that time to the present."

To the distillation theories of Newberry and Peckham, Orton raises the objection that they do not harmonize with the facts of geology in the main oil fields, and discusses these at some length. He, however, accepts in his earlier writings the essential point in Hunt's theory of the origin of petroleum, "that it results from the primary decomposition of organic substances," but without subscribing to his views that it was produced contemporaneously with the rock, nor that it is especially a product of limestones. In his later writings, however, he seems to have held that this theory was not fully sustained by the facts, and says:

"What geologists would be glad to find in nature as matching to and harmonizing with the facts with which they are obliged to reckon would be a process in which the products of the organic world are transformed into mineral oil at ordinary temperatures and with complete consumption of the substances acted on, so that no carbon residue would be left behind. They would also expect the transformation to be accomplished while the organic matter still retained essentially its original character."

He is strong in his belief that petroleum is the primary product and that the other members of the bituminous series—namely, natural gas, maltha, or mineral tar, and asphalt—are derived from it. In his last printed report, he says of it:[5]

"Petroleum seems to be, when thus protected from the air, one of

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[4] P. 42.

[5] Petroleum and Natural Gas in New York, *Bulletin No.* 30, *N. Y. State Museum* (1899).

the durable forms that organic matter can assume. There seems no reason to believe that it is less permanent than coal. Stored in the rocks in the morning of the world it can apparently remain in this condition through the vast and indefinite ages of geology."

In the decades that have passed since the publication of these views, the principal advance which has been made in the theories relative to the formation of petroleum is the development of the theory that the first step in such formation is the separation and segregation of the fatty materials from the remains of plants and animals by the action of bacteria. Upon this point there now appears to be substantial agreement among most geologists. As to the manner, time, and place of the transformation of these fatty materials into petroleum, however, they are, seemingly, as far apart as ever.

A review of the publications bearing on the subject indicates that by far the greatest number of writers, both American and European, still hold by the theory that the production of petroleum from the fatty matters is brought about by some form of pressure or temperature acting on the materials after they have been entombed in the rocks.

Engler says:

"The transformation of the fatty materials into petroleum has been accomplished under very diverse conditions of pressure, of temperature and in cycles of time of different duration."[6]

Dr. David White, speaking of the rapid disintegration of animal matter in sapropelic deposits, says:

"This forcibly suggests that the algæ, which almost certainly have exerted an attraction for certain bitumens of extraneous origin, may have played the important rôle, first of storing up some of the hydrocarbon products of the decaying animal matter; and later, under dynamic influences, of releasing a part, at least, of the stored, as well as, presumably, of their own original contents in the form of petrolic or gaseous hydrocarbons.

"There is little doubt in the mind of the writer that the oils and gases of the Mesozoic and Tertiary, as well as of the Paleozoic, are directly derived, in most cases at least, from dynamic distillation of algal débris, though in part originally of animal origin."

He thus attributes its production to a time subsequent to the deposition of the beds containing the algal débris.

Similarly, Dr. F. W. Clarke, without expressing his views as to the direct cause of the transformation, believes this transformation to take place after burial:

"Wherever sediments are laid down, inclosing either animal or vegetable matter, there bitumens may be produced. The presence of water,

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[6] Int. Pet. Cong., Bucarest, vol. ii, p. 35 (1910).

preferably salt, the exclusion of air, and the existence of an impervious protecting stratum of clay seem to be essential conditions toward rendering the transformation possible."[7]

Cunningham-Craig also states his belief in the derivation of petroleum by pressure-distillation of organic matter (terrestrial vegetation) buried in the rocks:

"It seems probable—but here we enter into speculation—that it is the *pressure* that is the determining factor, as it is in so many chemical reactions. Given the vegetable matter from which petroleum can be formed enclosed in a well sealed deposit, given the presence of a limited quantity of water, and the necessary, but by no means high, temperature, as soon as the pressure reaches a certain point the action will begin."[8]

While it is not denied that petroleum can be, and has been, produced by a process of distillation from organic matters entombed within the rocks beneath the surface of the earth, the arguments adduced by Orton against the probability of such pressure distillation having taken a prominent part in the production of the principal accumulations of petroleum from entombed organic débris are just as valid against the claims of more recent writers who invoke its aid in the transformation of the buried fatty matter derived from such organic materials.

Orton's arguments have been repeated and added to by Dalton, Clarke, and others, and seem to me to be in full accord with facts of observation. Professor Hoefer also comes out positively against this theory of pressure distillation and substitutes for it a process of fermentation.

One of the early statements by Dr. Hunt regarding oil in the limestones is as follows:[9]

"The facts observed in this locality appear to show that the petroleum, or the substance which has given rise to it, was deposited in the beds in which it is now found at the formation of the rock. We may suppose in these oil-bearing beds an accumulation of organic matters whose decomposition in the midst of a marine calcareous deposit has resulted in their complete transformation into petroleum."

He thus indicates the probability that the formation of petroleum is, or may be, contemporaneous with the deposition of the rock material.

This has been more clearly stated by Murray Stuart:

"The oil represents a contemporaneous flow and was deposited in practically its present state,"[10] and in his adaptation of the existing theory of the derivation of oil from the fatty materials of plants and animals in the sediment itself to suit the altered view that oil is of sedimentary origin in the deposits and is not a secondary product in them, he says:

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[7] *Data of Geochemistry,* p. 703 (1911).

[8] *Oil Finding,* p. 28.

[9] Tenth Census, p. 62.

[10] Geological Survey of India, vol. xl, p. 320.

"For this purpose it is necessary that the decomposition of the organic bodies should have proceeded elsewhere than in the strata themselves and yet in such a place that the oil would be retained and collected until it was liberated upon the surface of rivers which were depositing the sediment."[11]

Munn, on the contrary, while also holding to the contemporaneous formation of petroleum with the sediments in which it is found, holds that it is generated in the loose mud and sand on the sea bottom, coming off very probably in microscopical globules and "because of the great affinity of oil for clay, each of these tiny globules immediately after being formed eagerly seized upon the first small particle of clay with which it came in contact and completely enveloped all exposed portions of it"[12]

It will be noted that both Stuart and Munn are discussing only the origin of petroleum found in the shales or the sandstones connected with them into which it may have migrated. The method of deposition outlined by Munn is based on the supposed affinity between the clay particles and oil globules, while Stuart maintains that "The deposition of oil is purely a matter of gravitation. The oil becomes mechanically mixed with the sediment and the fineness of that sediment renders it impossible for the oil to separate itself; the mixture of sediment and oil, being still of higher specific gravity than water, falls to the bottom and is deposited as a sedimentary deposit."[13]

We have here in contradistinction to the prevalent theory that the transformation of the fatty materials derived from organic remains into petroleum takes place after the burial of these materials in the sedimentary rocks, through the action on them of pressure distillation, or by some geo-chemic process, one which postulates the formation of petroleum from similar material, by natural processes, at the surface of the earth, without the interposition of geo-dynamic or geo-chemic agencies, and its contemporaneous deposition as petroleum with those sediments with which it is originally connected.

If this view, which has also been advanced by other writers than those named, can be maintained, even in part, it will, it seems to me, afford us an explanation of the origin of many petroleum deposits, the conditions surrounding which do not appear, in any wise, to fit the pressure-distillation theory.

The actual formation of petroleum and other bitumens at the surface of the earth in such relation to other sediments as might permit their deposition in the manner claimed for them seems to be fairly well established by observations in various parts of the world.

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[11] Geological Survey of India, vol. xi, p. 239.

[12] *Economic Geology*, vol. iv., No. 6, p. 519 (Sept.,-Oct., 1909).

[13] Geological Survey of India, p. 324.

"In 1866 Lesquereux . . . . . . referred to the recent formation of a liquid akin to petroleum in Sardinia and Sweden. In the former the salt-marshes are frequently covered with masses of sea-weed, and these can be observed decomposing into petroleum-like oil. In Sweden on the shores of the Sound in the neighborhood of Lund, sea-weed buried in the shore sand has been found to decompose into a similar substance."[14]

Newberry reports "that in the Bay of Marquette, where the shore consists of peat overlying Archean rocks, bubbles of marsh gas arise, together with drops which cover the surface of the water, in spots, with an oily film."[15]

Krämer and Spilker call attention "to a possible derivation of petroleum from diatoms, which abound in certain bogs. These organisms, according to Krämer and Spilker, contain drops of oily matter, and from diatomaceous peat a waxy substance, resembling ozokerite, can be extracted. . . . . .

"Krämer and Spilker's views have not met with very general acceptance, but they seem to contain elements of value. H. Potonié's hypotheses, for example, seem to be a broadening of Krämer and Spilker's. This writer calls attention to the 'faulschlamm' or 'sapropel,' a slime, rich in organic matter, which is formed from gelatinous algæ, and accumulates at the bottom of stagnant waters. Such a slime, Potonié believes, may be the parent substance from which bitumen, by a process of decay, was probably derived. In this connection, and with reference to the adequacy of the proposed source, it is well to remember the enormous accumulation of 'oozes,' namely, the raidolarian and globigerina oozes, on the bottom of the sea. The organic matter thus indicated is certainly abundant enough, if it can decay under proper conditions, to form more hydrocarbons than the known deposits of petroleum now contain."[16]

Dalton, discussing Krämer and Spilker's studies of the Gulf of Stettin, says:

"Opinions are divided as to whether ozokerite is a direct product of the decomposition of organic matter or of the natural desiccation and oxidation of liquid petroleum, but the researches at least point to the fact that natural decomposition of plant remains, especially of the lower forms, may give rise to petroleum-like substances."[17]

Observation of the direct formation of petroleum is given by Clarke as follows:

"E. Sickenberger has shown that in small bays of the Red Sea, where the salinity reaches 7.3 per cent., petroleum is actually forming as a

[14] Dalton: *Economic Geology*, vol. iv, No. 7, p. 616 (Oct.–Nov., 1909).

[15] Clarke: *Data of Geochemistry*, p. 701.

[16] *Idem.*

[17] *Economic Geology*, vol. iv, No. 7, p. 618 (Oct.–Nov., 1909).

scum upon the surface of the water. Living forms are abundant in these bays, and their remains, after death, furnish the hydrocarbons. The latter are to some extent absorbed into the pores of coral reefs, and so contribute to the formation of bituminous limestones. A still earlier publication by O. F. Fraas, contains data of similar purport. Fraas found in Egypt shells filled with bitumen, and noticed that the bituminous beds were rich in fossils, while the nonbituminous strata were poor. In the region of the Dead Sea, also, Fraas noticed that bitumen was abundant in beds of baculites, from which it exudes to accumulate upon the shore. In this connection it may well be noted that the brines which are so often associated with petroleum have, as a rule, a composition indicative of a marine origin, and do not resemble solfataric or volcanic waters. Furthermore, Mendeléef's objection to the possibility of forming petroleum at the bottom of the sea—namely, that being lighter than water it would float away and be dissipated—is not only negatived by Sickenberger's observations, but also by the well-known fact that mud and clay are capable of retaining oily matters mechanically. The littoral sediments probably aid in the process of petroleum formation, if only to the extent of retaining the fatty substances from which the oil is to be produced. The beds of sulphur which occur adjacent to some oil wells, notably in Texas, were probably formed by the reducing action of organic matter upon sulphates, such as gypsum, a mineral which is often associated with marine deposits and with petroleum. The association of gas, oil, salt, sulphur, and gypsum, which some writers have taken as evidence of former volcanism, is much more simply interpreted, both chemically and geologically, as due to the decomposition of organic matter in shallow, highly saline waters near the margin of the sea."[18]

Dalton refers to other similar observations as follows:

"Natterer describes the occurrence of petroleum in the mud of the Mediterranean sea-floor between Cyprus and Syria, and in the sea-water immediately above the bottom; it was also found in the Gulf of Suez, and in each case ammonia and iron sulphide or sulphur occur with the oil. . . . . . But the present value of the 'Pola' observations lies in the fact that they show that at least in the Levant and the Red Sea so much organic matter is being buried in the sediments that the petroleum formed by its decay not only impregnates these rocks of the future, but is distributed through the lowest strata of the sea itself, sulphur or sulphides being also formed in the process."[19]

Dr. David White, while upholding the pressure-distillation theory for the production of petroleum, recognizes the fact of the formation of

[18] Clarke: *Data of Geochemistry,* pp. 699, 700.

[19] Dalton: *Economic Geology,* vol. iv, No. 7, p. 620 (Oct.–Nov., 1909).

other bitumens by organic processes in connection with the decomposition of fatty algæ mingled with animal matter in stagnant or quiet waters.

". . . . . the animal bacteria may have completed their work after the extinction of the plant bacteria beneath the surface of the rapidly increasing organic accumulation. The writer is disposed also to believe that the bituminous elements derived from the fully decomposed animal remains have participated to a very important extent in the infiltration of the thalli of the undestroyed algæ, thus enriching the latter with combustible matter of a distinctly bituminous character."[20]

"An important point to be borne in mind is that the attractive selection of the bitumens and the consequent enrichment of the algal matter appears to have been accomplished during the first or biochemical change of coalification."[21]

The actual formation of petroleum and other bitumens in peat bogs, at the bottoms of bays, along the margin of the sea and even on the sea-floor, would, therefore, appear to be as well established as any of the facts upon which the pressure-distillation theory is based.

The association of such petroleum with sediments in course of formation, as already recorded, and the readiness with which surface petroleum is carried down and deposited by muddy waters are facts in favor of contemporaneous deposition, which is further sustained by many field observations which seemingly admit of no other explanation. This is especially true of the coastal fields of Texas and Louisiana.

The productive oil sands in this region are overlain by heavy blue clays, massive in structure and so dense as to be impermeable either to water or oil. They are known locally as "gumbo." These gumbos carry some included lenses of shale, but these are as a rule not individually extensive. They also carry small pockets of pulverulent gypsum and some iron pyrites.

In drilling wells throughout this region it is a common thing to find shows of oil, or pockets of oil, in the midst of these dense clays, as well as in the included shales. In a recent well drilled at Terry, in the eastern part of the State, we had several such shows of dark oil from the gumbos and one of nearly white oil from a small bed of shale hundreds of feet above the productive oil sand, and so separated from it by dense layers of gumbo that they could not possibly have been derived from it. The same conditions were observed in many wells drilled at Saratoga, Welsh, and in other coastal fields. So far as can be known there is no outside source for these oil shows, the clays have not been subjected to any special heat or pressure, or any decided earth movement, and the most

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[20] *Economic Geology*, vol. iii, No. 4, p. 308 (June–July, 1908).
[21] *Ibid.*, p. 311.

probable derivation that can be suggested for them is that the petroleum was deposited with the clays.

Our experience in drilling wells in the Mexican oil fields has shown similar occurrences of pockets of oil and gas in the highly impervious shales and gumbo, which overlie the oil-bearing limestones and in some cases a thousand or more feet above them. It is true that there is abundant evidence that volcanic forces have been active in this region, as basalt is found in the form of intrusive sills as well as in extrusions in some parts of the field, so that in many cases oil or gas may have come up from the producing beds into overlying strata through fractures caused by this action, but the special occurrences I have here in mind are from wells which are not so related to any of these basalt beds or extrusives as to warrant the belief of such an origin. Furthermore, if they had followed up from below they should be found more abundantly in the sandier and more porous portions of these shales, which is not the case.

In northwestern Colorado and northeastern Utah the Mesaverde beds of the Upper Cretaceous are both coal-bearing and petroliferous. The basal portion of the Mesaverde which carries these deposits is made up of two bands of sandstone separated by a belt of clay shales. This is generally known as the Rim rock in this region.

Going westward from Meeker the coal beds gradually thin, until in the vicinity of Vernal they are no longer of the economic importance of those further east.

A little west of Rangely the sands begin to show indications of oil, and these increase to the westward, until the oil sands acquire very considerable thickness. At one locality an oil or asphaltic sand overlies a coal seam which is seemingly impregnated to some extent with the asphalt.

West and south of Vernal the outcrop of the Rim rock bears northwest to southeast, and the entire thickness of the formation at this point is but a small part of that at Meeker, or even at Rangely. It is also the highest member of the Cretaceous exposed at this place, being directly overlain by the basal beds of the Wasatch, with an entire absence, not only of any trace of the Lewis shale or Laramie, which are found in the eastern portion of these coal fields, but of the upper members of the Mesaverde itself as found further east. Gale says of this at another locality:[22]

"It is therefore presumed either that beds corresponding to those now found in the Yampa field had been eroded from the Rangely district and vicinity before the deposition of the Tertiary beds began, or that the uppermost Cretaceous beds were never deposited in the Rangely district. In the latter case, the time during which these later beds were

[22] *Bulletin No.* 350, *U. S. Geological Survey,* p. 23 (1908).

being laid down in other regions was marked by dry-land conditions in this district."

In either event this particular region must have been a land area for a time prior to the beginning of the Wasatch deposition, as is shown by its erosion prior to the deposition of the Wasatch beds and the character of the basal Wasatch conglomerate.

Six miles south of Vernal the exposure of the Mesaverde shows a thickness of 1,100 ft. and is overlain by the Wasatch beds.

Four miles southwest of Vernal, by erosion of the upper beds, less than 600 ft. of the Mesaverde sandstone remain. Of this, the upper 150 ft. of sands as exposed in the Church quarries are rich in bitumen, petroleum residue, evidently a partly exhausted oil pool.

Six miles west of Vernal the Rim rock of bituminous sandstone comes to an end and the Wasatch conglomerates seem to overlap upon the underlying Mancos shale.

The Wasatch, which is in contact with the Mesaverde at the Church quarry, has thick beds of conglomerate and sand rich in oil residue, and many of the pebbles, cobbles, and boulders composing it are worn fragments of the Mesaverde oil or tar sands immediately below. Many of these cobbles are equally rich in bitumen with the Mesaverde oil sands from which they came and richer in oil than the sandy matrix in which they are now imbedded, showing that the Mesaverde at this locality was the exposed edge of an "oil pool" in early Tertiary time when the Wasatch beds were being laid down.

While this cannot be claimed as conclusive evidence of the contemporaneous deposition of petroleum with the Mesaverde sediments, the time limit between the deposition and extrusion is comparatively a short one as measured by geologic units, and the probabilities are, at least, in favor of this assumption.

Like conditions, also, occur in the Arbuckle mountains a few miles south of Sulphur, Okla. Here rich oil sands of the Ordovician were exposed in mid-Carboniferous time. The succeeding and now overlying Carboniferous conglomerates contain bitumen-rich boulders or limestone and sandstone taken directly from the Ordovician beds. Not only were the Carboniferous conglomerates and sands built up by the actual transfer of the bituminous material, but the contact relations of the once oil-bearing Carboniferous sands to the petroliferous Ordovician limestone and sandstone beds below are such as to suggest a strong probability that the Carboniferous beds were enriched by the migration of oil from the Ordovician.[23]

The facts brought out by Dr. Orton in his discussion of the theories of transformation, already alluded to, seem also to have a direct bearing on this question.

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[23] J. A. Taff: *Tishomingo Folio* and personal communication.

Dr. Newberry's theory that no unusual temperature is needed for the production of oil by his process of "spontaneous distillation" is practically the same as that of more recent writers who, in their advocacy of pressure distillation, suppose that extended periods of time may take the place of that intensity of action which is required in our laboratories for the accomplishment of these results. This theory would imply that if organic substances, such as are petroleum producing, still remain in beds at depths and temperatures comparable to those which have in times past yielded petroleum, then petroleum should still be in process of formation in them. This applies to buried fatty materials just as fully as to other organic matter, if fatty materials are necessarily the fundamental form of matter for the production of petroleum. Furthermore, among the buried strata which have escaped wholly or even partly the effects of geo-dynamic action, there should be beds which would show some of this potential petroleum as imbedded fatty matter, but I know of no such record. So far as we know, the bitumens exist in the rock as such, fully formed, and most other organic matter, even that which may be regarded as "potential petroleum," because it will produce petrolic oils by destructive distillation, or possibly by so-called pressure distillation or geo-dynamic forces, exists as "coalified" carbonaceous material.

Dr. Orton, speaking of the great shale formation of New York, Ohio, Pennsylvania, and Kentucky, says:

"Petroleum is present in all fresh samples of bituminous shale, not potentially, but actually, existing in them *as* petroleum, and the amount is susceptible of measurement. . . . . . .

"It must not be inferred from these statements, however, that the shales monopolize the petroleum of the bedded rocks of the Mississippi valley. The claim that the limestones are distinctly petroliferous is abundantly established by examination of the various strata. Every important member of the entire scale contains, disseminated through at least portions of its extent, petroleum in large enough amount to admit of measurement. The Trenton limestone, the Clinton, Niagara, Lower Helderberg, Corniferous and St. Louis limestones, each and all furnish conspicuous examples of its presence in noteworthy amount."[24]

As has been noted, Munn and Murray Stuart make no claims for the contemporaneous deposition of petroleum in any but shale beds, but it would seem that no obstacle intervenes to prevent the extension of this theory to limestones as well, and in this manner include the earlier theory of Hunt, especially if algal remains be recognized as one of the very important factors in the production of petroleum. Dr. David White has called especial attention to the prevalence of algal remains in various oil rocks, and Dr. Clarke has indorsed the suggestion of Bailey Willis,

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[24] Orton: *Kentucky Geological Survey*, p. 50.

that some marine limestones have been formed by plant agencies, with the following statement:

"In the shallow seas which are thought to have covered a large part of the North American continent the calcium carbonate may well have been thrown down by algæ. To produce a permanent deposit, however, the water must have been too warm to carry much carbonic acid in solution, and too shallow for the precipitate, while sinking, to redissolve."[25]

Blackwelder,[26] in a recent paper, suggests that the "structures" which form so large a part of the Bighorn dolomite of Wyoming are of algal origin, and notes the strong odor of petroleum emitted by the rock when freshly broken.

Deposition of such petroleum-producing materials as are recorded by Krämer and Spilker and by Potonié, or of petroleum, not only could have been, but evidently has been, made in such seas as this also, and contemporaneous deposition with the consequent limestones is as much a fact as with the shales formed from the muddy sediments observed by them and others.

While many, if not all, of the theories advanced as to the production of petroleum have in them some elements of truth, and while we believe that under diverse conditions petroleum may be and is formed in many different ways, the theory here outlined which recognizes the formation as petroleum under suitable paludal, bog, or marine conditions, at ordinary temperatures, by natural processes, the transformation being accomplished while the organic matter still retains essentially its original character, and its deposition as petroleum with other sediments of its day, seems well supported by observational facts, and its very simplicity and general applicability appear to offer strong grounds for the belief that it will sooner or later come to be recognized as one of the principal methods of the formation and accumulation of petroleum.

In such case, all indigenous or primary deposits of petroleum would be of the same age as the sediments in which they occur and those of secondary or migrating oil would be of different age from the inclosing beds.

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[25] *Data of Geochemistry*, p. 526.

[26] *Bulletin of the Geological Society of America*, vol. xxiv, No. 4, pp. 607 to 624 (Dec., 1913).

The Illinois Oil Fields

BY H. A. WHEELER, ST. LOUIS, MO.

(New York Meeting, February, 1914)

CONTENTS

History

Illinois has so recently attained the third place in the oil production of the United States that few realize its great importance, or are aware of its highly profitable character. Since 1907 Illinois has furnished about 15 per cent. of the United States output and about 10 per cent. of the world's production. The value of the output in 1913 is estimated at $30,000,000, of which about $20,000,000 is profit.

The present prosperity dates from 1905, but efforts have been made since 1865 to develop production and geologists have been very sanguine as to its future for over 25 years. Had the oil operators been as confident as the geologists, the field would have been opened at least 30 years earlier. For the rich Eastern Illinois oil field is located along the La Salle anticline, that was mapped 46 years ago by Professor Worthen in the

first geological survey of the State.[1] Prof. T. B. Comstock enthusiastically wrote in 1887[2] about the highly promising character of this anticline, to which he again called attention in 1889.[3]

The writer's studies in 1888 were convincing as to its oil future, yet to have then advocated drilling would have earned the reputation of being a dreamer. In fact, as late as 1903 the writer's suggestion to a prominent Pittsburg oil operator to prospect in Illinois met with contempt and derision, which was representative of the general feeling then held by the oil fraternity, yet this same party made a large fortune four years later out of a block of Illinois oil leases.

The first commercial wells were brought in at Litchfield, 50 miles northeast of St. Louis, where in 1882, in drilling for coal, gas was discovered that supplied the town several years. Later, some oil wells were brought in that until 1902 produced a lubricating oil that sold for $5 a barrel.

In 1887, at Sparta, 40 miles southeast of St. Louis, in drilling for water, gas was discovered that supplied the town about 20 years, and in 1906 several oil wells were brought in half a mile northeast of the gas wells.

In 1890, in drilling for water, gas was discovered near Pittsfield, in Pike county, that later developed into a field over 10 miles long.

The present highly prosperous era dates from 1904, when a small gas well was drilled near Casey, in Clark county, by J. J. Hoblitzell, who was induced to prospect at Oilfield on the showing of oil and gas made by some old wells that had been drilled in 1865 by Chicago parties. The latter drilled several wells on the evidence of oil and gas seepages, but, although a little was found, the wells were a failure from not casing off the water; *i.e.*, they were drowned out. Several more small wells were brought in, but they were so discouraging that they failed to interest the scouts that flocked in when leases were only $5 to $10 an acre. When a 40-barrel well was subsequently brought in, the "talent" promptly scurried after leases, which rapidly advanced to $100 to $200 an acre, and since then the Eastern Illinois field has rapidly developed along the La Salle anticline. The southern extension was discovered in February, 1906, in Crawford county and by midsummer the adjoining Lawrence county began producing. The Allendale pool, at the south end, was discovered in September, 1912. Shipments by tank cars started in June, 1905, and within a year the first pipe line reached the field, followed by four others that had a daily capacity of 112,000 barrels by 1909.

On the western side of the State, the Butler oil and gas was discovered in 1907, the Centralia pool in 1908, the Greenville, Carlinville, and Sandoval pools in 1909, and the Carlyle pool in 1911.

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[1] *Geological Survey of Illinois*, vol. iii (1868).

[2] Oil and Natural Gas in Illinois, *Proceedings of the Illinois Society of Engineers and Surveyors*, vol. ii, p. 92 (1887).

[3] *Engineering and Mining Journal*, vol. xlviii, No. 26, p. 565 (Dec. 28, 1889).

The total production to Jan. 1, 1914, is 209,018,914 barrels, valued at $156,025,398, as shown in Table I. This record for output and values has never been equaled by such a young field, as it requires time, as well as capital, to develop a new field, especially where there was such a lack of confidence. While the latter has disappeared since 1906 on the eastern side of the basin, it still holds as regards the western side of the basin.

Table I.—*Summary of Illinois Oil Production*

Year	Output Barrels	Value	Stocks Dec. 31 Barrels	Producing Wells	Average Price
1905	181,084	$116,561	....	189	$0.64
1906	4,397,050	3,274,818	2,509,598	3,093	.75
1907	24,281,973	16,432,947	15,751,305	7,353	.68
1908	33,686,238	22,645,881	29,209,660	10,372	.67
1909	30,898,339	19,788,864	32,343,887	11,152	.64
1910	33,143,362	19,699,383	31,324,784	12,171	.59
1911	31,317,038	19,734,339	24,063,870	12,753	.63
1912	28,601,308	24,332,605	15,709,738	13,222	.85
1913	22,512,522	30,000,000	5,613,372	14,000?	1.32
Total.....	209,018,914	$156,025,398			

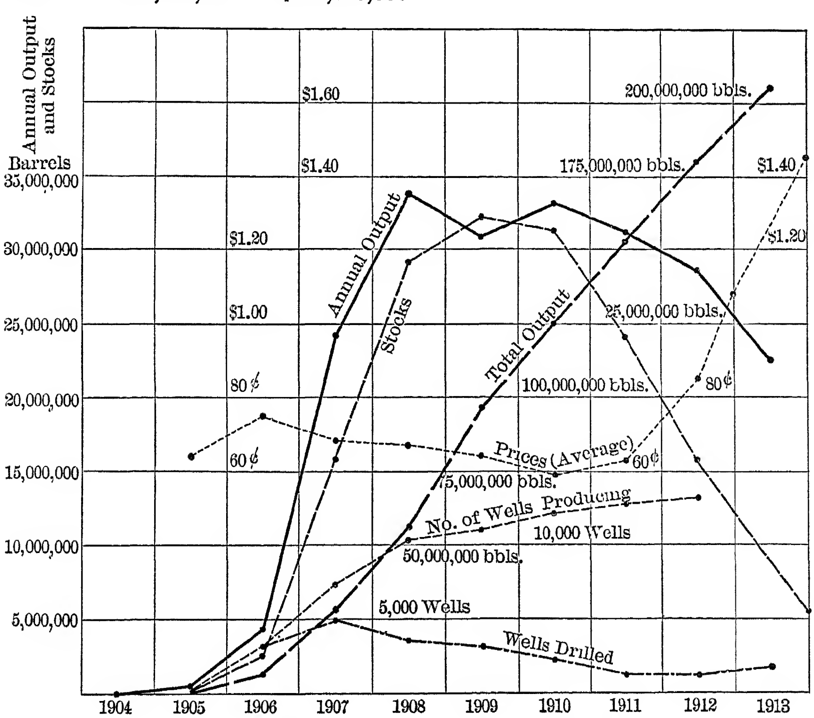

Fig. 1.—Chart Showing Output, Stocks, Prices, and Wells, Illinois Oil Fields.

Since 1904, 21,730 wells were drilled up to Jan. 1, 1914, of which 82.9 per cent. were producers, that came in with an average daily production of 38.5 barrels per well, according to the monthly statistics published by the *Oil City Derrick* (Oil City, Pa.). This average is based on tank gaugings, and while it is much below the popular estimates, it is high compared with the other high-grade oil fields. The value of wells averaging 38 barrels will be appreciated when it is considered that a 100-acre lease in Illinois that averages 10 barrels per well usually nets 100 to 125 per cent. on the investment.

A condensed *résumé* of the Illinois oil statistics is presented in the diagram, Fig. 1, which shows the annual production, the total production, surplus stocks, average annual prices, the oil wells drilled, and the number of producing wells.

Location

The Illinois oil fields are in the southern half of the State and consist of two groups, known as the Eastern and the younger Western fields.

The Eastern Field.—The Eastern field is situated along the eastern edge of the State and mainly in Clark, Crawford and Lawrence counties, with slight extensions into Edgar, Coles, Cumberland, Jasper, and Wabash counties. The strike is quite regular and runs about 20° west of north. The length in Illinois is 66 miles from the Westfield pool at the north end to the Allendale pool at the south end. The field crosses the Wabash river at St. Francisville and extends 45 miles through the southwestern portion of Indiana and continues 50 miles southward to Hartford, in Kentucky, where several wells were brought in last summer. This gives a length of over 160 miles along the La Salle zone of deformation on which oil and gas have been developed. A marked change occurs beyond the Illinois border, as the field becomes very irregular and highly spotty, at least as far as developed, and lacks the remarkable reliability and continuity that characterize it in Illinois. The width of the field ranges from 2 to 4 miles at the northern end and from 5 to 12 miles in the central and southern portions. The field seems to be over 20 miles wide in Crawford county, but this is undoubtedly due to a cross anticline, the influence of which is seen in the new pools being opened in Sullivan county, Ind., which adjoins it on the east.

The accompanying three maps, Fig. 2, illustrate the development of the field when respectively two, four, and nine years old. They show that it is premature to define the limits, as the boundaries are constantly extending, and new sands are being brought in. A study of these maps shows that at the end of two years, when about 4,000 holes had been drilled, apparently less than 25 per cent. of the area along the anticline was productive. At the end of four years, when about 12,000 holes had been drilled, fully 50 per cent. was found to be productive. At the end

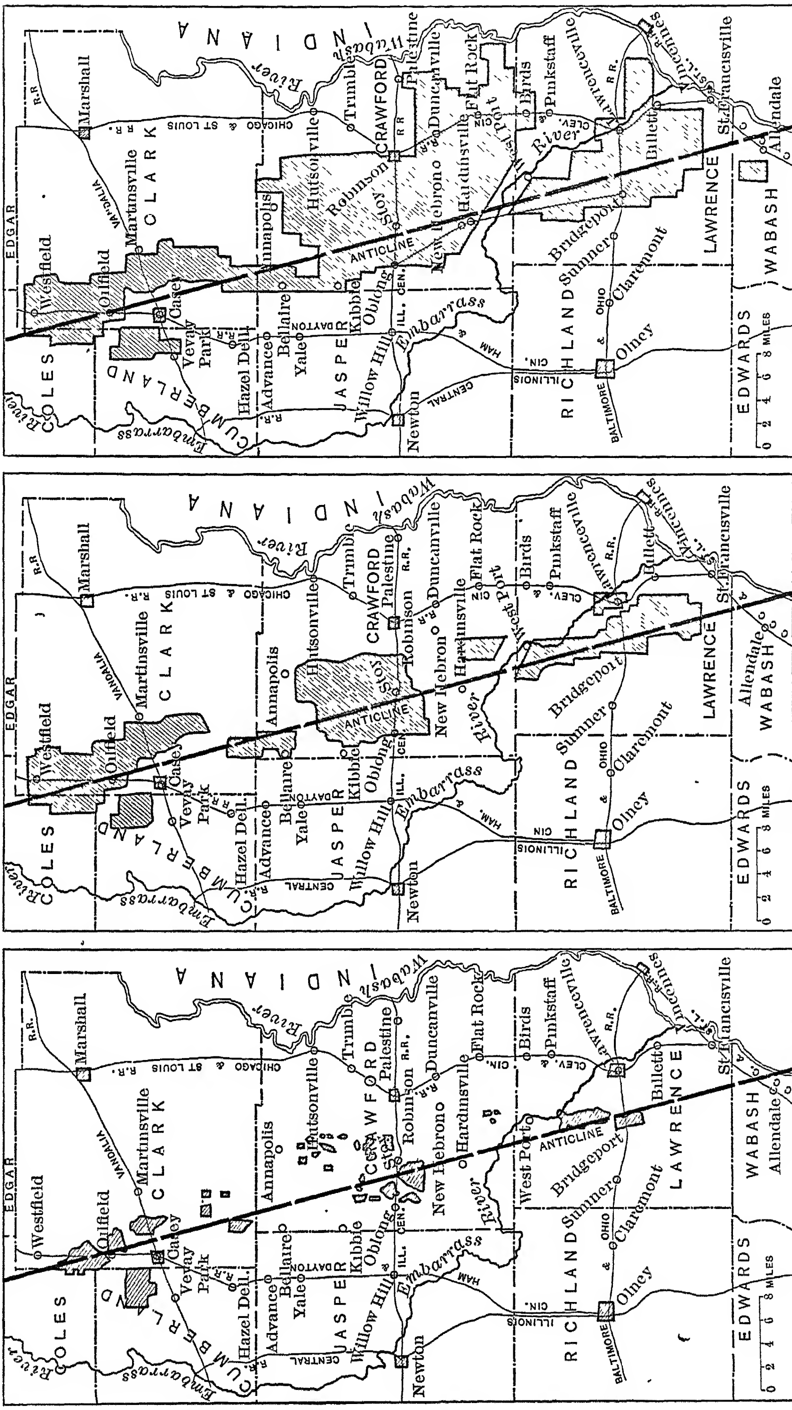

FIG. 2.—DEVELOPMENT OF THE EASTERN ILLINOIS OIL FIELD, OPENED IN 1905.

of nine years, when about 21,000 holes had been drilled, over 80 per cent. had proved productive. The Eastern Illinois field to-day is the largest, most regular, and most reliable individual oil field in the United States. If the Allendale pool is omitted, there is only one break in its

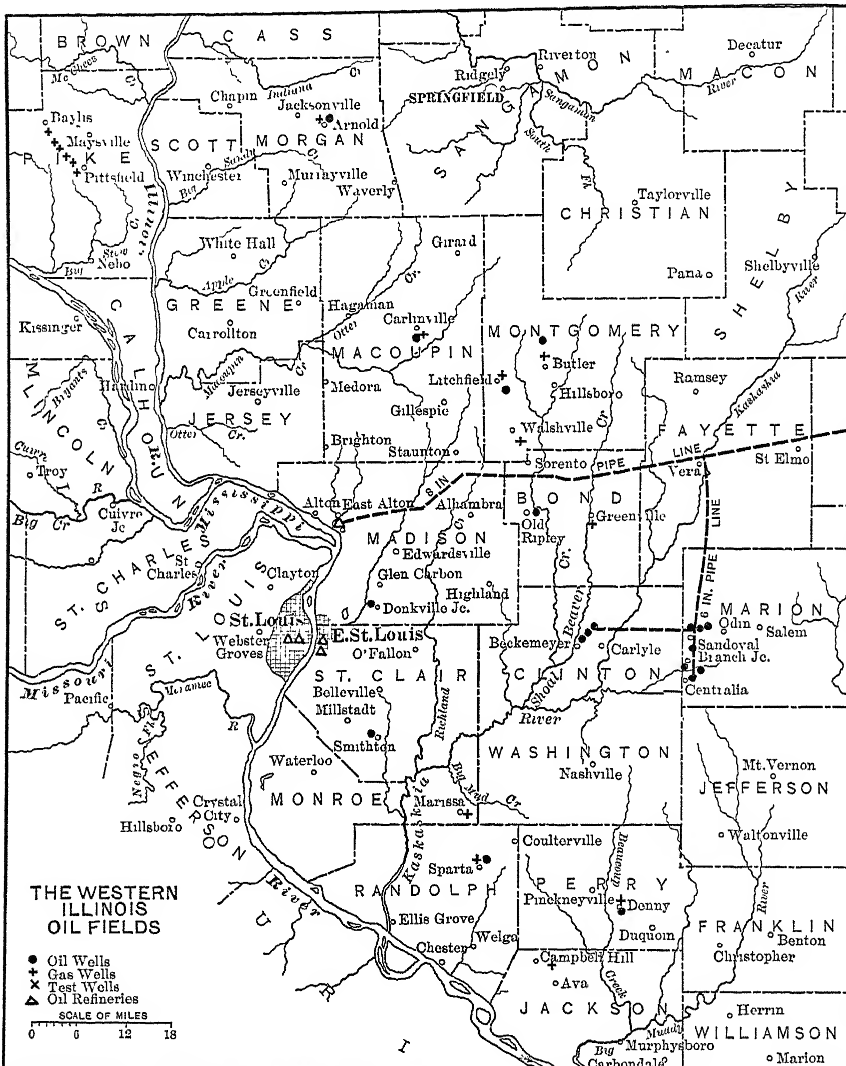

FIG. 3.—MAP SHOWING WESTERN ILLINOIS OIL FIELD.

continuity in 60 miles, or where the Embarrass river crosses the anticline. While to-day several miles separate the Allendale pool from the main field, more thorough drilling may show that the intervening ground

is productive, as this has repeatedly happened in the past eight years' experience.

The Western Field.—The Western Illinois oil and gas field is situated in Marion, Clinton, Bond, Montgomery, Macoupin, Morgan, Pike, Madison, St. Clair, Randolph, Jackson, and Perry counties, as shown on the accompanying map, Fig. 3. As the western flank of the Illinois basin is about three times larger than the eastern, and as there are more anticlines, it will probably develop into a larger field and ultimately produce more oil, although this prediction to-day seems as rash as earlier ones made by the writer that have since made good. For the sands and other favorable formations are practically identical on both sides of the basin, while the more numerous western anticlines have a much larger collecting area to supply them. As the Western field lacks the simplicity and regularity of the Eastern field, it will be more difficult to prospect and the percentage of dry holes will be larger, especially if developed in the haphazard manner in which most prospecting is carried on by "practical" oil men. For the attitude of most oil operators toward the aid that can be rendered by geology and trained experience is similar to that of the steel maker 50 years ago about a chemist—"an amusing scientific chap who uses big words but knows nothing about making steel."

Geology

Structure.—The geological structure of Illinois is comparatively simple and regular, like its topographic features, which latter mainly consist of a very slightly undulating sheet of glacial drift 50 to 150 ft. thick through which occasional sluggish streams have sometimes eroded to bed rock.

Under the flat prairie surface occurs a spoon-shaped basin. Its north-and-south axis is 400 miles long and its width is 140 to 180 miles. The basin is occupied by alternating sediments, mainly of Carboniferous age, that have a maximum thickness of about 2,000 ft. The formations thin out, die out, and outcrop toward the north and thicken and increase in number toward the south. The oil-bearing "sands" tend to decrease in richness toward the north, as a result of this thinning of the beds, and tend to enrich toward the south, from the thickening of same, until they come within the malignant influence of the Ozark uplift. Thinning and impoverishment of the oil sands toward the north also occur in the similar Mid-Continent oil field (Oklahoma and Kansas), in which the present production is also derived from the coal measures, and a similar uplift ruins the southern end of the field.

Upon the flanks of the Illinois basin occur anticlines, or folds, or elongated domes, which in water-charged sediments are the natural traps, or zones of arrest, or concentration areas, of oil and gas. The

anticlines vary considerably in the amount of the doming and are relatively flat and broad compared with those of Pennsylvania. They are usually flatter and less persistent in the Western field and tend more to the type of a series of domes along the uplift, rather than a continuous ridge type as in the main Eastern field.

Coal Measures.—The oil thus far produced in Illinois, with minor exceptions, is derived from the Carboniferous system, or the coal measures, which consist of alternating shales 5 to 150 ft. thick, limestones 2 to 50 ft., bituminous coals 1 to 8 ft., and sandstones 5 to 60 ft. The accompanying well section illustrates the variety and thickness of the formations, in which only the basal sandstone (the Ferruginous, or Benoist) carried oil at this particular place. The six sandstones between 915 and 1,439 ft. frequently contain oil at other places, especially in Lawrence county, while two shallow sands did not show in this well, of which the Dykstra (600 ft.) produced oil 2 miles west of this hole.

The shales fluctuate greatly in color, texture, and thickness and are always the predominating formation. The limestones are usually thin and, with one exception, are not persistent. The coal seams are generally thin, or 1 to 3 ft., excepting No. 6, and occasionally Nos. 5 and 2, which range from 4 to 8 ft. The thin seams are not persistent, while No. 6 is remarkably persistent in western Illinois and is easily recognized by its limestone roof. The sandstones are usually porous, are firm and stand up well, and are generally water-bearing. The porosity varies considerably, and to a less extent the fineness of grain, which largely explains the variations of different wells in the same field when not complicated by a variable thickness.

Type Section of an Illinois Oil Well

The Langewich Well, Centralia; 70 Barrels

Formation	Thickness Feet	Depth Feet
Sandy clays (drift)	155	155
Shale	10	165
Limestone	10	175
Shale	90	265
Limestone	20	285
Black shale	67	352
White shale	8	360
Black shale	115	475
White shale	25	500
Black shale	115	615
Limestone	10	625
Coal—No. 6 seam	7	632
Black shale	18	650
Limestone	25	675

Formation	Thickness Feet	Depth Feet
White shale	40	715
Dark shale	33	748
Coal No. 5.	5	753
Black shale	42	795
White shale	50	845
Black shale	30	875
Limestone	12	887
Black shale	13	900
Limestone	15	915
Sandstone—dark	15	930
Black shale	80	1,010
Sandstone—salt water	11	1,021
Black shale	16	1,037
Sandstone—salt water	43	1,080
Black shale	20	1,100
Limestone—hard	25	1,125
Black shale	51	1,176
Limestone and shale	50	1,226
White shale	24	1,250
Black shale	45	1,295
Sandy limestone	10	1,305
Sandstone—dark	38	1,343
Dark shale	25	1,368
Sandstone—white	23	1,393
Limestone	17	1,410
Shale	14	1,424
Sandstone	15	1,439
"Red rock" (shale)	11	1,450
Dark shale	5	1,455
Limestone	30	1,485
White shale	30	1,515
Limestone	7	1,522
"Pencil slate" (caves)	30	1,552
"Red rock" (shale)	8	1,560
Shale	32	1,592
Oil sand—9 ft. pay	39	1,631

(The "big lime" is probably at 1,650 to 1,700 ft.)

Sub-Carboniferous.—The following successively deeper measures occur in Illinois, some of which have an assured future as oil producers:

The Sub-Carboniferous, or the Mississippian, immediately underlies the coal measures and is 500 to 1,000 ft. thick. It consists mainly of limestones and is known as the "big lime" by the drillers. An upper bed (the St. Genevieve) that is known as the "McCloskey sand" is occasionally oölitic and has proved the richest in the State, as the wells occasionally come in at 1,000 to 4,000 barrels.

Beneath the "big lime" occurs a shale bed that when sandy was found to carry oil and gas along a small anticline in St. Louis on the

western fringe of the basin. Like all thick limestones, even when mostly non-magnesian, like this, there is always the possibility of crevices and chambers serving as reservoirs for oil accumulation that are likely to produce good wells. While such reservoirs are erratic and will be difficult to find, they suggest occasional wells. The 200 water wells drilled about St. Louis in this formation occasionally show oil, which indicates that where artesian conditions have not washed away the oil valuable wells will be found.

Where a fault has exposed the "big lime" as a bold bluff near Grafton, 30 miles northwest of St. Louis, it is soaked with oil for about 125 ft. This "oil in sight" stimulated considerable drilling in the neighborhood that resulted in dry holes, as the oil that once filled the limestone escaped millions of years ago through the "knocking out of the head of the barrel" by the fault. This exposure is highly important in almost assuring large wells when this horizon is tapped under a thick cover with favorable structural conditions.

Recently wells of 10 to 25 barrels[4] have been found in Oklahoma in the "big lime,"although the prospect drilling in that field, as in Illinois, has almost invariably stopped at the top of this formation. As the geology of the Oklahoma and Illinois fields is similar in many respects, the developments in either field are likely to prove helpful in prospecting the other.

The Devonian.—The Devonian formation is usually thin, or 2 to 10 ft., where it outcrops along the Mississippi river, on the western edge of the basin, and is generally a black shale. It has been found over 100 ft. thick, and when sandy is likely to be an important, though erratic, producer of oil. Some oil of excellent grade, or 39° B., was found in the Devonian at Old Ripley, in Bond county, 40 miles northeast of St. Louis, at 2,000 ft., and also at Peters, 10 miles northeast of St. Louis, at 1,300 ft., but at both places the sand was very thin and hence the wells were small.

The Niagara Limestone.—The Niagara limestone is 50 to 200 ft. thick. The Pike County gas field at 150 ft. in western Illinois and the recently developed deep sand (2,800 ft.) at Casey, in eastern Illinois, are in this formation. The famous old crevice well at Terre Haute, Ind., 30 miles east of Casey, also is in the Niagara lime. Where this limestone is dolomitic, and consequently porous, as in Pike county, it is likely to prove a productive horizon if anticlines or other structural conditions are favorable.

The Trenton Limestone.—The Trenton is 200 to 400 ft. thick and is partly a porous dolomite and partly a compact limestone. A shale that occurs with it is so heavily soaked with oil as to burn like a candle and is known as "oil rock" where it outcrops for about 300 miles along the

[4] Since the above was written, a 250-barrel well has been struck at Big Heart, Okla., at a depth of 300 ft. *in* the "big lime" and with a surface depth of 2,200 ft.

western fringe of the basin. This is the formation that carries the oil and gas in the adjoining Indiana field and also in the Lima field, of western Ohio. As it is usually 2,500 to 3,500 ft. deep in southern Illinois and has a thick shale cover, it is likely to be a rich gas producer, as the great depth has probably prevented leakage. It is a promising formation for both oil and gas and underlies the entire oil field, though at varying depths.

Very Deep Sands.—About 200 to 400 ft. below the Trenton occurs the St. Peters sandstone, which is usually 100 to 200 ft. thick and generally coarse and very porous. Still deeper are the "second" and "third" sandstones, that are interbedded with magnesian limestones. While these are possible oil horizons, there are features that are not encouraging, while the depth will be 4,000 to 5,000 ft.

Oil Conditions.—The chemical, physical, and structural conditions in Illinois are ideal for the occurrence of profitable oil pools, and the geologists incurred little risk in predicting their discovery many years in advance of the drill. For there is an abundance of material to produce the oil in the bituminous shales, organic formed limestones, and coals. There are numerous porous beds to act as reservoirs in the porous sandstones and dolomites. There are many shales to act as impervious covers, or "stoppers to the bottle." There is a continuous dip on the sides of the basin to permit gravity to rearrange the original concurrent association of water, oil, and gas. There are anticlines to trap or arrest the ascending oil and gas and concentrate them into pools, and the magnitude of the basin is sufficient to insure large pools. Stratigraphic conditions have prevented artesian circulation, at least in the lower sands, thus preventing the washing away and dissipation of the oil after reaching the anticlines. Faults and dikes are either absent, or are so slight in the main part of the basin as not to interfere with the accumulation of the oil, or to cause its dissipation. While these conditions have been known to the geologist for a long time, it is only since 1905 that they have been demonstrated to the satisfaction of the oil operators on the eastern side of the basin. The oil men are still skeptical as to the western field, which is only in the infancy of its development, and they have thus far lacked the courage to test the deeper horizons below the coal measures.

Description of the Eastern Illinois Field

The Eastern field is situated along a strong anticlinal fold known as the "La Salle," as it passes through the town of La Salle in northern Illinois, where it is a heavy fault. As the axis of the anticline dips south, the sands deepen and increase in number and thickness to the southward. The No. 6 coal seam, which is well marked and persistent in western

Illinois, serving as a valuable datum plane, is frequently absent in eastern Illinois, or is difficult to recognize, so that the correlation of the "sands" is uncertain. All of the sandstones (or "sands") are more or less lenticular, as usual, or thicken and thin, come in and die out, although two of them are surprisingly persistent.

The field is divided into three districts, each of which has marked individuality, which are known as: 1, the Clark County, or Northern, or Shallow, district; 2, the Crawford County, or Central, district; and 3, the Lawrence County, or Southern, or Deep, district.

The Northern District.—The Northern district is mainly in Clark county, with slight extensions into Edgar, Coles, and Cumberland counties. Casey is the commercial center, which, like the other towns in the oil belt, has greatly grown and prospered since the field opened in 1905.

Most of the wells are 350 to 400 ft. deep and are in a light gray, porous, dolomitic limestone that has 8 to 30 ft. of pay. The wells come in at an average of 25 barrels, ranging from 5 to 50 and occasionally at 100 to 200 barrels per day. The small cost of a well resulted in considerable over-drilling, with a consequent rapid decline, and many wells were abandoned when they fell off to one to two barrels with oil selling at 60c. to 68c. Recently the abandoned leases have been re-drilled and again made very profitable, especially as another oil horizon has been found 40 to 100 ft. deeper, that comes in at 10 to 50 barrels.

In the Siggins pool, 2 miles west of Casey, a sand occurs at 600 ft. that is 20 to 60 ft. thick and came in with 10 to 100 barrel wells and plenty of gas.

Oil shipments by rail began in June, 1905, and in the following three years the field developed rapidly. Since then the extensions have been slight and there was little activity until last year, when a second pay was found at about 450 ft. The district is producing about 7,000 to 8,000 barrels daily.

Recent deep drilling near Westfield, at the northern end of the field, has found a dark-green, high-paraffine oil at 2,750 ft. As the wells are small for such a deep sand, or 10 to 20 barrels thus far, only a few have been drilled and they are on the western edge of the pool. They are probably in the Niagara limestone, as are the Terre Haute well, 30 miles east, and also the Pike County gas field, in western Illinois.

The Crawford County District.—The Central, or Crawford County, district, with Robinson as the commercial center, is the largest in area and has made the highest output, as 100,000 barrels a day were produced in 1907. It occupies the greater part of Crawford county, with a slight overlap into Jasper county on the west, and extends to Indiana on the east. The great width of over 20 miles that the field seems to have is undoubtedly due to a cross anticline that extends into Sullivan county, Ind.

The main producing horizon occurs at about 900 ft. and is known as the Robinson sand. It ranges from 8 to 30 ft. in thickness, averaging 20 ft., and the wells come in with an average of about 30 barrels per day, ranging from 5 to 100 and occasionally 200 to 500 barrels. A sand known as the Kibbe occurs at 750 ft. in the northern part of the county, and deeper sands occur at 1,100 and 1,400 ft. (the latter resting on the "big lime") over portions of the field, but they are narrower and less reliable than the Robinson sand.

The district was opened in February, 1906, by the discovery of the rich Shire pool, near Oblong, as the result of wild-catting started by a salted well. The latter opened the field at least a year earlier than would have resulted from conservatively edging southward from the Casey district. Four very active years of drilling followed, that rapidly enlarged the field, and for the past six years it has been a consistent producer, as the average well came in at 22 to 28 barrels. There has been considerable over-drilling, especially where the early wells were large, and the wells have therefore declined to a very moderate production. The daily output of the district is about 12,000 to 15,000 barrels.

A local, but unsuccessful, company drilled several tests about Robinson in 1901 to 1903, that found trifling amounts of oil and gas. Developments since then show that some of the holes were located in the pool, and had intelligent advice been secured the efforts would have been rewarded with huge profits. This experience of the pioneers failing where later followers have reaped generous rewards has been repeatedly duplicated in Illinois. Within the past few months town-lot wells are being drilled in Robinson, which was condemned by the earlier oil men from the neighboring dry holes. Another very reliable pool, where 42 good wells were consecutively brought in on one lease, was discovered 18 months ago in the heavily condemned territory 3 miles north of Robinson.

The Lawrence County District.—Lawrence county, at the southern end of the field, is probably the richest producer of high-grade oil of any county in the world. A few pools have attained a larger initial production, but the nine sands and their great staying power have enabled Lawrence county to maintain a daily production of 40,000 to 60,000 barrels for the past seven years. Yet the first three tests were dry holes in what has since proved to be the heart of the pool. The old oil operators were afraid of it and promptly sold out in its early development, as there was no gas. It occupies the greater part of Lawrence county, with a small extension to Allendale on the south, in Wabash county. Bridgeport is the commercial center, where the field was opened in 1906 with town-lot wells. The latter are still profitable producers, which is one of the rare exceptions where such excessive well density has paid.

The development of the field has been steady and consistent, as the depth and high cost of drilling have discouraged over-drilling. The

first wells were opened in the Bridgeport sand at about 900 ft., which came in at 20 to 100 barrels; later, other lenses of Bridgeport sands were developed at 780 and 1,000 ft. Later drilling brought in the Buchanan sand at 1,300 to 1,400 ft., the "Green Oil" at 1,525 to 1,575; the Kirkwood at 1,590 to 1,625; the Tracy at 1,700 to 1,790, which has produced wells of 1,000 to 2,000 barrels; and the McCloskey at 1,840 to 1,900 ft. The latter is an oölitic limestone, the St. Genevieve, in the upper portion of the Mississippi lime, and is very rich, as it has produced 2,000 to 4,000 barrel wells; the oil, like the Tracy sand, has a gravity of 37° to 39.5° B. Recent developments have brought in the Richey sand, at 550 ft., that was overlooked in the earlier work.

Three to five of the above sands are often found productive on one lease, to each of which separate wells were formerly drilled. In recent practice, one well is made to serve several sands by perforating the casing at each horizon.

The Allendale pool, in Wabash county, was discovered in September, 1912. Only one sand has thus far been found, at 1,500 ft., which produces a 37° gravity oil, but with no gas. The wells come in at 20 to 800 barrels, but decline rapidly, and the pool is small and spotted.

The daily output of the Lawrence County district ranges from 42,000 to 50,000 barrels.

Description of the Western Illinois Field

The Western Illinois oil field is so much younger than the Eastern field, with two minor exceptions, that the output is much less, although the sands are essentially the same and also the grade of oil. The developments of the next five years will probably witness a large increase in the output, and ultimately it will probably surpass the eastern side of the basin. For the western flank is about three times as large as the eastern limb of the Illinois basin and the anticlines are more numerous. It will develop less rapidly, however, as it lacks the simplicity of the Eastern field, especially if prospected in the erratic, unscientific method usually pursued.

Marion County.—In sinking a coal shaft 2 miles north of Centralia, in 1908, oil seeped in at 600 ft. from a small fault, which stimulated drilling in the vicinity. A strong north-and-south anticline at this place had been previously mapped by the Illinois Geological Survey, but, as usual, this was ignored by the oil men. Several 5-barrel to 20-barrel wells were brought in near the shaft in the Dykstra, or 600-ft., sand.

In the following year two light wells were brought in 2 miles east of Centralia in the 1,600-ft., or Benoist, sand and 75-barrel wells since then; the log of one of these, the Langewich well, is given on a preceding page. In the Dunn well, 2 miles northwest of Centralia, the oil was found in the Stein, or 1,400-ft., sand. Another oil sand, though light, was reported

at 1,300 ft. in the Wireback well that was drilled last fall $2\frac{1}{2}$ miles east of Centralia, in which the Benoist sand was found at 1,685 ft.; this is unusually low and explains why the oil was light and the salt water heavy, as it was too far down on the anticline (too far east) to expect oil. It is difficult to obtain reliable information about the Centralia pool and it has the earmarks of being held back until more leases are obtained.

Prospecting for the extension of the Centralia pool in 1909 brought in a good well at Sandoval, about 6 miles north on the same anticline, and in the following year a rich pool was drilled in. A sand was struck at about 1,400 ft. (the Stein) that came in at 25 to 50 barrels and at 1,550 ft. the Benoist sand came in with wells of 50 to 400 barrels and averaged 110 barrels per day. As the Benoist sand is 20 to 40 ft. thick and has great staying power, the wells are all sunk to this horizon and production in this field is the highest priced in the State. There is plenty of gas in both sands, and the No. 6 coal seam is found at 600 ft. The Benoist sand rests on the "big," or Mississippi, lime.

The Centralia district is connected by a 4-in. and the Sandoval district by a 6-in. pipe line with the Ohio Oil Co. lines, while Sandoval also has a 4-in. independent line to loading racks on the B. & O. R. R.

Marion county has the highest record in the State for initial production, as the U. S. Geological Survey statistics[5] for 1910 show that 60 wells came in with an average daily output of 110.6 barrels; Lawrence county is second, at 102.7 barrels in 1910 and 105 barrels in 1912, when the very rich McCloskey sand was discovered.

Clinton County.—In prospecting in 1910 along an anticline near Carlyle, to which attention has been drawn by the Illinois Geological Survey, a 100-barrel well was brought in at 1,020 ft. after three previous failures. Hundreds of oil men rushed in and bought up leases in every direction, paying $5 to $10 an acre 10 miles distant up to $250 an acre near the discovery well. A rich pool was rapidly developed and the wells came in at 20 to 1,000 barrels per day, with plenty of gas. Another sand at 800 ft. that was overlooked in the first rush has since been developed and came in at 10 to 30 barrels.

The Carlyle pool is connected by a 6-in. pipe line with the Ohio Oil Co. lines.

The 123 wells brought in during 1911 in Clinton county came in with an average daily output of 95 barrels, the highest in the State that year, and which has only been exceeded by the adjoining Marion county at 110.6 barrels (the highest in the State), and by Lawrence county (eastern Illinois) at 105 barrels in 1912.

Bond County.—Drilling at Greenville in 1910 developed a gas sand at 950 ft. that has since furnished light and heat for that town, the wells coming in at 2,500,000 cu. ft. per day.

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[5] *Production of Petroleum in* 1912, U. S. Geological Survey, p. 68 (1913).

Subsequent drilling at Old Ripley, 10 miles west of Greenville, found oil at about 2,000 ft., in the Devonian formation. The sand was very thin, or about 2 ft., and the wells were so small, or 5 to 25 barrels, that they were abandoned, as oil was then selling at 60c.

Montgomery County.—The first commercial gas and oil found in Illinois were developed at Litchfield, at about 600 ft., in 1882. The gas was discovered in drilling for a lower coal seam and it supplied the town for several years. Further drilling in 1886 found several small oil wells that produced until 1903 a lubricating oil that sold for $5 a barrel. In drilling for coal at Butler, 8 miles east of Litchfield, in 1907, gas was discovered at 600 ft., and two miles north a similar heavy lubricating oil was found in the same sand, but developments were stopped by litigation.

Macoupin County.—Drilling at Carlinville in 1909 found gas and a little oil (2 to 5 barrels) at 400 ft. in the same sand as at Litchfield and Butler, that has since supplied that town. On drilling half a mile east of the gas wells last summer wells of 40 to 100 barrels were brought in from the same sand and a local pipe line was built to the field.

Pike County.—In drilling for water near Pittsfield, in 1890, gas was struck at 168 ft. in the dolomitic Niagara limestone, but no use was made of it until 1905. Since then a field 10 miles long by 4 miles wide has been developed along an anticline and nearly every farm has its own gas well.

Randolph County.—In drilling a water well at Sparta, in 1887, a strong flow of gas at 350 lb. pressure was struck at 900 ft. that supplied that town for over 20 years from some 20 wells. In 1906 oil was found in several wells over a small area on drilling about half a mile northeast of the gas field. While one well came in at 100 barrels, most of them were small, and shipments have about ceased. An investigation of the well records by the Illinois Geological Survey shows that the wells were drilled on a local "wart" or very small dome in a synclinal basin, which clearly explains the large number of dry holes that surrounded the small oil pool.

Morgan County.—Small amounts of oil and gas were found near Jacksonville, in 1910, at 300 ft., which is the most northerly occurrence that suggests commercial value. As the sands thin and die out going northward, the prospects are not encouraging in northern Illinois.

Madison County.—At Peters, 10 miles northeast of St. Louis, excellent oil was found in 1905, in the Devonian, at about 1,300 ft., but as the sand was very thin the wells were too small to pay.

St. Clair County.—At Smithton, several small oil wells were brought in during 1911, at 150 ft., at the base of the coal measures, along an anticline that extends northeast through O'Fallon. As the oil sand outcrops a few miles southwest it is surprising that any oil was found, but prospecting northeastwardly along the descending axis of the anticline should be successful when deep enough to be beyond the leakage zone.

At Marissa, gas and oil were noticed in 1895 in drilling a water well, which led to further drilling in 1912. Two good gas wells were brought in at 600 ft. As the neighboring coal mines show a strong, wide anticline, a field will probably be opened in the vicinity.

Jackson County.—A small gas well was brought in near Campbell Hill at 580 ft. in 1912 that led to considerable drilling in the vicinity; a little oil was found, but thus far not in paying quantities. This county is so far south as to be within the discouraging zone of faulting caused by the Ozark uplift and hence there is grave danger that the oil and gas have escaped, at least from the large pools that undoubtedly once existed.

Quality of the Oil

Over 92 per cent. of the Illinois oils grade above 30° B., which is the commercial line between low and high gravity oil. The Flat Rock oil is about 22° gravity, and occasionally oil in the Robinson and Casey sands grades at 28° B., on which there was formerly a dockage of 8c. a barrel; but for over a year all grades of Illinois oil have commanded the same price.

Broadly, the gravity of the oil improves with depth in Illinois, as the oils from the shallow sands in Clark, Crawford, and Macoupin counties are relatively heavy, or from 28° to 32° B., while the oils from the deeper sands in Lawrence, Marion, and Clinton counties will range from 34° to 39.5° gravity.

The color of the Illinois oils is very dark green to dark brown, except the deep Casey oil, which is light green and high in paraffine.

The Illinois oils have a paraffine base, except in the Bridgeport and Flat Rock sands, which have as much as 5 per cent. of asphalt.

The oils are "sweet," or essentially free from sulphur, as the latter averages 0.2 per cent., ranging from 0.1 to 0.5 per cent.

The gasoline content, like the gravity, improves with depth, as the Clark County or shallow oils have 8 to 18 per cent., the Crawford county oils have 8 to 20 per cent., and the deep Lawrence county oils have 10 to 23 per cent., while the heavy, asphaltic Flat Rock oil has only 1 to 4 per cent. The average gasoline content is about 15 per cent.

The kerosene content ranges from 25 to 38 per cent. and averages about 31 per cent.

The Oil Sands

All but two of the so-called "sands" in Illinois are sandstones, and, on account of the dip of the basin, the depth of the same sand will vary according to the distance from its outcrop. On the eastern side of the State the depth increases toward the west, and on the west side, which is much the longer flank, the depth increases eastwardly at 10 to 15 ft. per

mile. There is a secondary general dip of the northern three-fourths of the State to the south, due to the dip of the axis of the spoon-shaped basin to about Jefferson county, when the axial dip reverses, with a much sharper dip to the north, and the southern, or stub, end of the basin comprises about a fourth of the State.

When not carrying oil or gas, most of the Illinois sands are saturated with salt water and dry sands are local. Even on the anticlines, if a sand is thick, oil and gas frequently occur in the upper portion, while the lower part of the sand may be full of salt water.

Two of the oil-bearing sandstones are quite persistent and fairly uniform over large areas of Illinois, while the other sandstones are lenses of greater or less magnitude and consequently are more or less uncerta n. The lenticular, uncertain character of most of the oil sands harmonizes with the other formations of the Illinois coal measures, as, barring No. 6 coal seam and one or two limestones, the limestones, coals, sandstones, and shales fluctuate greatly in persistency and thickness—in fact, to such an extent that it is often difficult to correlate reliable logs of different wells on the same lease.

Basal Sand.—The most persistent and easily recognized "sand" rests on the "big lime" and was formerly known as the Ferruginous sandstone. It generally ranges from 20 to 50 ft. in thickness, is usually coarse and porous and is the Sparta gas and oil sand, the Benoist sand of Sandoval and Centralia, the "deep" sand of Crawford county, and the Tracey sand of Lawrence county. The wells usually come in at 50 to 150 barrels, ranging from 5 to 1,500 barrels per day.

Robinson Sand.—About 200 to 300 ft. above the basal, or Ferruginous, sandstone occurs another sandstone that is very persistent and more frequently carries oil or gas. This is the "big-pay" sand at Carlyle, the gas sand at Greenville, the oil and gas sand at Litchfield, Butler, and Carlinville on the west side, and is the equivalent of the Robinson sand in Crawford county and the Kirkwood in Lawrence county. This sand is 5 to 50 ft. thick, averaging 15 to 25 ft., is usually quite uniform, rather coarse, and stands up fairly well. It produces wells of 20 to 100 barrels, with extremes of 5 to 1,500 barrels per day.

Casey Sand.—The 400-foot, or Casey, sand in Clark county is a dolomitic limestone, which is unusual in the coal measures, as the limestones are seldom magnesian. The dolomitization has rendered it porous and therefore capable of serving as a reservoir. The wells come in at 17 to 30 barrels, with extremes of 5 to 200 barrels per day.

McCloskey Sand.—The McCloskey sand in Lawrence county is an oölitic horizon (the St. Genevieve) in the upper portion of the Mississippian limestone. Its porosity is due to the spaces between the spherical granules of which this formation is composed, and as these are large and excessively numerous it produces very large wells, or from 50 to 4,000

barrels per day, the largest thus far found in Illinois. The excessive, coarse porosity that is responsible for such large wells also results in the oil soon draining out; hence the wells soon decline to a modest output.

Drilling Features

Contracting.—Drilling is generally done by contract, as few companies operate their own tools. The contractors furnish the equipment and deliver a completed hole on a footage basis, also including the casing if desired, though usually the latter is supplied by the producer. "Machines," or portable rigs, are generally employed up to 1,200 ft., although some contractors use derricks for the 400-ft. wells. The derrick is used when over 1,200 ft. and is usually wood, though a few composite, or "turn-buckle," rigs are employed, and rarely the all-steel derrick. The derricks are erected by special rig-builders at an expense to the operator of about $700, as they are usually left on completion of the well for subsequent cleaning and pulling.

As the fire clays under the coal seams frequently cave and as there are several water sands above the oil, a large amount of casing is required. For wells not over 1,000 to 1,200 ft., the hole is started with 10-in. or 12-in. drive pipe, followed by $8\frac{1}{4}$-in. casing, and the oil sand is entered with $6\frac{5}{8}$-in. casing; deeper holes are started with 16-in. drive pipe and sometimes finished with $5\frac{1}{16}$-in. casing. The gas pressure is usually so light that it is imperative to enter the oil sand with a "dry" hole; that is, the overlying waters must be shut off by casing. For if the hole is full of water a rich oil sand might be passed through and reported as a trace, or a "showing," from the hydrostatic pressure holding back the oil in the sand, or "drowning the oil." This is what delayed the opening up of the Casey district some 40 years. When the hole caves, underreaming bits are used, which permits the casing to follow closely after the tools, thus preventing them from getting buried under the cavings. Crooked holes occasionally give trouble from the tools being diverted by striking a "nigger-head," or the tough, hard, spathic iron concretions that occur in some of the shales.

The prices paid for drilling in the Casey and Crawford districts, where machines are used and there is no caving, range from 70c. to 80c. per foot. In Lawrence county, the rates are 90c. to $1 to the Bridgeport sand (900 ft.) and $1.30 to $1.50 to the deeper sands, where more or less underreaming is required. In western Illinois, where there is more or less caving, the rates are $1.15 to $1.25 per foot up to 1,100 ft. and $1.40 to $1.50 to the 1,600-ft. sand. These rates are subject to modifications according to haulage and whether the operator furnishes the fuel and water. For cleaning out the hole, etc., after shooting, the charges are $20 to $25 a day.

Drillers are paid $5 and back-hands or tool dressers $4 per 12-hr. shift, with two men "on tower" while drilling and both crews, or four men, when setting or pulling casing.

For "wild-catting," or drilling at a distance from proven fields, the charges are higher, or usually $2 per foot, from the inconveniences and greater delays that result in isolated work.

The time required to complete a hole to the 400-ft. sand ranges from 4 to 8 days, as from 30 to 100 ft. are drilled per shift. It takes 14 to 24 days to drill to the 1,000-ft. sand and 30 to 60 days to the 1,600-ft. and 1,800-ft. sands.

Shooting.—Shooting has been the salvation of many Illinois wells that made only a feeble showing until shot, after which they came in at 25 to 50 barrels. Formerly heavy shots, or from 100 to 200 quarts of nitro-glycerine, were used, but so much sand trouble resulted that 20 to 80 quarts are now employed, depending on the thickness and softness of the sand. Several feet of bottom anchor are used where there is danger of breaking into water below.

The shots are fired with a battery, on account of caving trouble, and the charge is placed and wired before the $6\frac{5}{8}$-in. casing is pulled.

Well Density

Acreage per Well.—The usual practice in Illinois is to allow about 5 acres to each well, or they are spaced 400 to 425 ft. With 10 to 25 ft. of fine-grained sand this insures a slow decline and a reasonably long life. When the sands are thin, or so deep as to make the cost excessive, a well is given 7 to 10 acres, or they are spaced 500 to 600 ft. apart.

In the shallow sands, where the cost is light, the wells have frequently been placed much closer, or with only 1 to 3 acres to the well. While such over-drilling temporarily gives a large output, it results in a rapid decline of the wells and sinks an excessive amount of capital in a needless number of short-lived wells. When the leases are very small, or under 20 acres, or where very large wells are brought in, the rivalry among neighboring operators to secure as much of the oil as possible usually results in over-drilling, to the great advantage of the contractors and supply men, but at the expense of the ultimate profits of the operators. Town-lot wells seldom pay, as four to eight wells are drilled on an acre, which usually exhausts the oil so quickly that the investment is not always repaid. The wells in the town of Bridgeport are an unusual exception, as they have proved quite profitable, which is partly due to the staying power of the Bridgeport sand and partly to there being several sands. For the same reason the 1-acre school leases in Lawrence county, on which two to four wells have been drilled, have paid well.

As an extreme case of excessive well density in a normal field, yet one

that has proved highly profitable, a sketch, Fig. 4, is shown of the McBride $\frac{3}{4}$-acre tract, 4 miles north of Bridgeport, that has been operated since Jan. 1, 1908, by the Silurian Oil Co. It is surrounded by four leases that call for 22 offset wells and to-day there are 30 wells on an area of less than 2 acres. Yet in 2,190 days it produced 200,000 barrels and to-day is yielding 55 barrels from 8 wells; this gives an average yield to date of 25,000 barrels per well, without including the flush production of 1907. Five wells are in the Bridgeport sand and three in the Buchanan, which are very thick, or 35 to 45 ft., which explains their

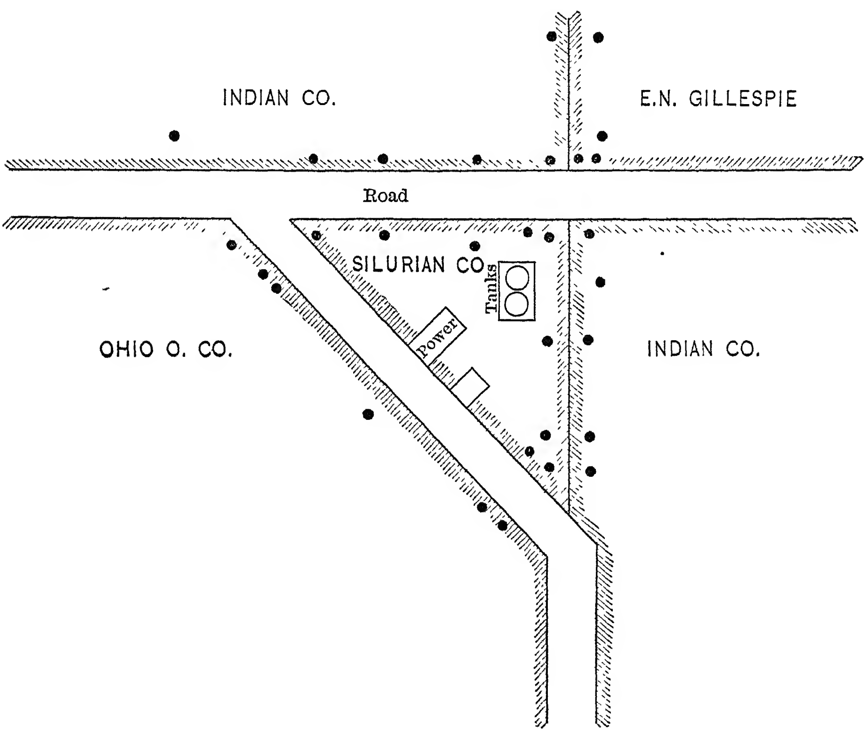

Fig. 4.—Thirty Wells on Two Acres, near Bridgeport, Ill.

ability to stand such a very heavy drain; they came in at 35 to 300 barrels. The sales from a gas well in the Kirkwood sand (No. 9) that came in at 5,000,000 ft. exceed $20,000.

To illustrate the richness of this territory when not overtaxed by excessive well density, a neighboring 40-acre lease produced 1,069,347 barrels in about 2,300 days from 17 wells in three sands, or over 60,000 barrels per well, and the wells are tanking 445 barrels per diem.

Offset Wells.—The unwritten law to locate line or boundary wells 200 ft. back from the property line has been quite well lived up to, and

there have been few line fights, outside of town-lot and similar small leases where disputes are unavoidable. The offset wells have usually been promptly drilled, especially in the early days when the wells were larger, and the drill is generally kept busy in developing a lease until all the line or boundary wells are completed. The inside locations are subsequently drilled deliberately and on many 40-acre and 80-acre tracts they have been omitted, as it is found that the line wells will eventually drain the interior of the lease.

Plant Equipment

Casing.—Casing is the heaviest investment on a lease and ranges from \$1 to \$1.50 a foot up to 1,000 ft., and from \$1.50 to \$2.50 in deep holes, or 1,400 to 1,900 ft. Formerly all the casing was left in a hole, but the larger sizes, or above $8\frac{1}{4}$-in., are now pulled and re-used. Casing requirements vary with every hole, but the following approximations cover most cases: A 1,000-ft. hole will require 50 to 200 ft. of 10-in. to reach the rock; from 200 to 600 ft. of $8\frac{1}{4}$-in. to shut off the upper waters; from 800 to 1,000 ft. of $6\frac{5}{8}$-in. to reach the oil sand. A 1,600-ft. hole will require 50 to 150 ft. of 16-in.; from 200 to 600 ft. of $12\frac{1}{2}$-in.; from 600 to 1,000 ft. of 10-in.; from, 1,000 to 1,400 ft. of $8\frac{1}{4}$-in.; and from 1,400 to 1,600 ft. of $6\frac{5}{8}$-in. Occasionally a string of $5\frac{3}{16}$-in. casing is employed to finish a hole, if water sands or the under-reaming have been excessive. The price of casing, which is subject to great variation, is about as follows, to which 5 to 20 per cent. should be added for freight, unloading, hauling, etc., to arrive at the cost at the well.

	Per Foot
16-in., $\frac{5}{16}$ thick (drive pipe)	\$3 25
$12\frac{1}{2}$-in., 36 lb. per foot (drive pipe)	1.20
10-in., 32 lb. per foot	0.85
$8\frac{1}{4}$-in., 24 lb. per foot	0.63
$6\frac{5}{8}$-in., 17 lb. per foot	0.45
$5\frac{3}{16}$-in., 13 lb. per foot	0.35

Derricks.—If a well is drilled with a derrick, it is usually allowed to remain for subsequent cleaning and pulling; otherwise portable pulling machines are employed when a well needs attention. As the high drilling derricks (64 to 84 ft.) are occasionally blown over, they are often replaced by 40-ft. pulling derricks, which are free from this danger.

Pumping Outfit.—The wells are equipped with 2-in. pumps and tubing as the salt water is seldom so heavy as to require a 3-in. pump. The pumps are connected to iron or wooden jacks that are operated by pull rods from a central power station driven by a 25 to 35 h.p. gas engine. The engine and power are housed in an inexpensive corrugated-iron building and from 4 to 24 wells are pumped from one power.

The 2-in. lead lines from the wells to the tank and the 2-in. gas lines that take off the casing-head gas aggregate 4 to 6 miles on a completely drilled 80-acre lease (15 wells). They should be buried over a foot to prevent freezing in winter, or tearing open from expansion in summer, and to be safe from breakage from the farmer's plow.

Tankage.—Liberal tankage is required, compared with Eastern fields, as from 2 to 10 tanks (wood) of 250 barrels capacity are required for a 100-acre lease. A "gun-barrel," or siphon, tank is also required for settling out the salt water, although small amounts of water, that only settles out in cold weather after thinning by steaming, are carried over into the shipping tanks. The tanks are housed in framed buildings to reduce the evaporation losses in summer.

A small boiler house located at least 100 yd. distant, so as not to fire the tank vapors, furnishes the steam for preparing the oil for shipping in cold weather and for operating the pipe-line pump.

Formerly the "B. S.," or the emulsion of oil, water, air, and sediment formed by improper pumping, was run off into special sludge ponds and burned, a very wasteful practice that is still quite prevalent. On the better-equipped leases the B. S. is treated in a sludge tank, by which considerable good oil is recovered. If the services of a capable chemist were retained practically all the B. S. could be recovered as good oil.

Market Features

Oil Prices.—Illinois is the only field that has gone through its "flush," or initial period of heavy production, and secured such high prices as 60c. to 68c. per barrel. Other fields have had to accept 3c. to 30c. during the inevitable heart-breaking interim that intervenes between overflowing field-tanks and the subsequent bringing in of sufficient pipe lines. This great advantage is due to its proximity to St. Louis and Chicago, where the oil would have found a welcome market at 40c. to 50c. in competition with coal.

When shipments began in June, 1905, the oil sold at 60c. and advanced to 83c. by June, 1906; after which it declined, remaining at 68c. throughout 1908 and again reached the low point of 60c. in October, 1909, where it remained until May, 1911. Since then, the price has continuously advanced and to-day, Jan. 29, 1914, it is selling at $1.45 in the open market, as paid by the Ohio Oil Co. (branch of the Standard Oil Co.). Independent buyers pay a premium of 5c. to 20c. a barrel, as on equal terms most producers prefer to sell to the Standard Oil Co., and it is only by giving a premium that they are able to divert it from the principal buyer. Formerly there was a discount of 8c. per barrel for oil below 30° B. gravity, but for the past year all grades have sold at the same price.

The oil is purchased in the producer's tanks after gauging and run off through the buyer's pipe line, with an extra allowance of 1c. to 2c. per barrel for the steam furnished to operate the buyer's pump that forces the oil into the pipe line. A dockage of 3 per cent. is usually made to allow for losses due to salt water, B. S., evaporation, leakage, etc. A "credit balance" ticket is made out by the buyer three days after the oil is shipped for the net barrels due the operator after deducting royalty and dockage. This ticket can be cashed at the market price for oil ruling that day, or it can be held to be cashed later, if higher prices are expected. Before the oil markets were stabilized by the present powerful interests, there were most violent fluctuations in oil prices that outrivaled Wall Street stocks, and operators who had the working capital held their tickets for the winter market, when prices generally ruled higher.

The unprecedented prosperity of the oil industry, the enormous increase in the demand for high-grade oils (paraffine base) to meet the rapidly expanding uses of gasoline and lubricants, and the almost complete exhaustion of the Illinois surplus stocks assure much higher prices for Illinois oil in the not distant future.

Storage.—As the Illinois oil is of too high a grade to be sacrificed for fuel, the large buyers built steel tankage to take care of the surplus oil before there were sufficient pipe lines. About 1,000 tanks of 35,000 barrels capacity were erected throughout the field, which contained about 33,000,000 barrels of oil in 1910. As the demand for Illinois oil has been much greater than the supply for the past three years, this surplus has been heavily drawn on to meet the deficit and to-day there remains about 5,500,000 barrels.

Pipe Lines.—No oil field has been as well taken care of in being promptly and completely equipped with pipe lines as Illinois. The magnitude of the field, the richness of the wells, and the high grade of the oil caused the pipe-line companies to go to enormous outlays to run the oil from the tanks of any and every producer and their total daily shipping capacity now exceeds 140,000 barrels.

The Ohio Oil Co. controls most of the lines, having a complete series of gathering lines throughout all the districts in eastern and western Illinois. It has an 8-in. line across the State to the Wood River refinery, 140 miles; two 8-in. lines to the Lima trunk line, 200 miles; and a 12-in. line to New York harbor, 900 miles. There is a pumping station at Bridgeport, in the Southern district, with 60,000 barrels capacity, that pumps the oil at 800 lb. pressure to Stoy, 25 miles, in the Central district. Another station at Stoy pumps the oil to Martinsville, 25 miles, in the Northern district, where all the oil from the Eastern field concentrates. From there it is distributed through the Eastern and Western pipe lines.

The Tidewater Co. has a 6-in. pipe line to the Atlantic seaboard and gathering lines throughout Crawford and Lawrence counties.

The Indian Refining Co. has gathering lines in Lawrence county, as also the Central and Sun companies, which run to their refineries at Lawrenceville.

The Leader Pipe Line Co. has gathering lines in Clark county for its refinery at Casey, from which the surplus oil is shipped to Pennsylvania refiners by tank cars. The Robinson refinery has gathering lines in Crawford county.

Railroads.—The five railroads that tap the Eastern Illinois field moved large quantities of oil before the pipe lines were completed and they still transport considerable oil for the smaller refineries from loading racks distributed throughout the field. While most of the refiners own their own tank cars, tank-car companies rent out hundreds of cars to the smaller shippers, at usually $1 per day.

The Western field is well equipped with railroads, which have thus far handled most of the oil.

Refineries.—Although most of the Illinois crude oil is piped to the large refineries on the Atlantic seaboard, there are nine refineries in Illinois that rely on the local output, of which six are on the eastern and three on the western side of the State.

At Lawrenceville is the large Indian refinery, of 9,000 barrels daily capacity, that makes a full line of products (gasoline, kerosene, lubricants, paraffine, etc.); the Central, with a capacity of 3,000 barrels, that co-operates with an asphalt plant, and the Sun Co. operates a 400-barrel skimming plant that makes gasoline and fuel oil.

There is a 600-barrel refinery at Robinson, a 600-barrel refinery at Casey, and a refinery at Chicago, the latter relying on tank-car shipments.

In western Illinois there are two refineries at East St. Louis that depend on tank-car shipments and a large refinery at Wood River, 20 miles from St. Louis, of 10,000 barrels capacity, owned by the Indiana Standard Oil Co.

Production Prices

The value of production and of operating leases has greatly increased as oil prices have advanced, and developed properties are almost unpurchasable. When oil was selling at 60c. production sold at $300 to $400 per barrel of daily output. When oil reached $1 it advanced to $800 to $1,000. At present, with oil at $1.45 to $1.65, production is held at $1,250 to $1,500 per barrel, according to the age and size of the wells, locations undrilled, royalty, condition of plant, equipment, and other modifying operating details. These prices are based on "settled" production, or after the flush period, or when the wells are about a year old.

Pennsylvania production, where the oil is higher grade, or 40° to 46° gravity, and sells for \$2.50 a barrel, is rated at \$2,000 to \$3,000 per barrel, although the wells yield only $\frac{1}{5}$ to $\frac{1}{2}$ barrel a day, and, like Illinois, it is almost impossible to induce a producer to sell at any price.

At these prices, the investment is expected to be returned in 1,000 to 1,200 days.

Royalties and Rentals

Eastern Field.—When the Eastern field was opened, the royalty was one-eighth of the production, or the customary rate in the older fields. When the field proved so rich, the competition among the oil men for leases resulted in the royalty advancing to one-sixth to one-fourth, and even three-eighths to one-half in extreme cases. The royalty on gas wells similarly increased from \$50 to \$100 per well annually to \$150 to \$200.

The rental to hold a lease good until a well is drilled was formerly 25c. to \$1 per acre annually, but lately \$1 to \$4 per acre is demanded, and then only 1 to 2 years allowed, compared with 5 to 10 years in the earlier leases.

Western Illinois.—In western Illinois the royalties and rentals are still reasonable, or one-eighth on the oil and \$50 to \$100 a year per gas well, while the leases can usually be carried 5 to 10 years without drilling on paying an annual rental of 50c. to \$1 per acre.

Cost of Oil Leases

The bonus, or cash price, paid to obtain an undeveloped lease varies greatly according to the distance from production, richness of the discovery well, and terms of the lease. Leases favorably situated on anticlines in an undeveloped territory go begging at a few dollars per acre until a discovery is made in the vicinity, when they quickly advance to \$25 to \$50 an acre if not over 5 miles distant, and to \$100 to \$350 an acre if within 2 miles. The discovery of a new pool promptly brings out hundreds of active, keen buyers from the old oil fields, who purchase at rapidly advancing prices every available lease for 7 to 15 miles in every direction. Leases 10 miles distant will bring \$5 to \$15 an acre from late comers after the nearer leases have been secured by the excited buyers. Within 30 days several million dollars will be invested in leases, of which 60 to 70 per cent. will probably prove unproductive. Yet pool after pool in Illinois (and elsewhere) has been the scene of repeated large investments in undeveloped oil leases around a discovery well by a horde of feverish buyers. While many speculators rush in to every new discovery, most of the buyers are old, seasoned oil operators who can no more resist the fascination of a "wild-cat" well that has made good than a tenderfoot can escape the lure of a mining boom in a gold camp.

Operating Expenses

The field expenses for producing oil in Illinois, including labor and upkeep, vary greatly according to size and conditions of the lease, the size of the wells, and amount of salt water. Excessive salt water requires the wells to be pumped by night as well as on the day shift and Sundays, whereas with little or no salt water day pumping suffices. As a pumper is generally required to every lease, whether it contains 40 or 160 acres, it makes the labor cost per barrel excessively heavy on the small leases, especially if operated double-shift. Similarly, if the wells are small, the labor costs per barrel are heavy compared with large wells.

The extra labor required for cleaning the wells, repacking, etc., will vary according to the condition of the wells, as old wells that have not been over-shot may have to be pulled only once or twice a year, whereas sand troubles caused by over-shooting may constantly require a pulling crew. The pumpers are paid $65 to $75 a month and live on the lease in a small cottage provided by the operators.

When an operator has several leases in a district a "farm boss" is employed, who keeps a crew of two to four "rousters" steadily employed in looking after the wells. The rousters are paid $60 to $70 a month and a farm boss from $100 to $115.

The usual field expense of putting the oil into the tanks ready for the buyer will range from 3c. to 7c. a barrel on leases of 80 to 160 acres, with large wells, or over 20 barrels per day; with smaller leases, or 20 to 80 acres, or where the wells yield 5 to 15 barrels, the cost will range from 7c. to 15c.; with very small wells, or 2 to 5 barrels, the cost increases to 15c. to 30c. per barrel.

When the leases are very small and in town-lot production, one pumper is usually put in charge of several leases and thus the labor cost is brought down to a reasonable amount.

Operating Profits

The net operating profits from Illinois oil production vary greatly according to the size of the wells, their staying power, depth and number of sands, size and age of lease, royalty, oil market, and other local conditions, besides depending on the capital invested for leases, drilling, plant, etc., and the individual operating costs.

The Illinois oil wells usually repay their cost in 30 to 90 days when not over 1,100 ft. deep and in 60 to 180 days in the deep sands, or 1,200 to 1,900 ft. Occasional large wells repay their cost in 5 to 20 days, while very small wells may take a year.

The capital for the acquisition, development, and equipment of an undeveloped property in a proven field is usually returned in the first year and will show the following great range: The lease will cost from $25

to $300 an acre, according to the distance from and richness of the discovery well; the wells will cost $1,000 to $8,000 each, according to depth; the plant investment for power, rodding, piping, tankage, boilers, buildings, etc., will range from $2,000 to $10,000, according to the size of the lease and local conditions. Yet many Illinois leases have returned the total capital invested in 4 to 16 months, when oil sold at 60c. to 80c. a barrel.

The net operating profits at present prices of oil ($1.45 to $1.60), after deducting the royalty and operating expenses, usually range from $1 to $1.30 a barrel. Small leases (5 to 20 acres), town-lot wells, very small wells (1 to 3 barrels), or excessive royalties (three-eighths to one-half), may reduce the net profit per barrel to 50c. to 80c.

A fair example of operating profits is shown in the following 120-acre lease in the shallow Casey field, where the wells came in at 10 to 50 barrels, seldom at 100 barrels per day, and the oil sold for 60c. to 82c. a barrel: The oil royalty was one-eighth, the cost of the lease was $100 an acre, and the wells cost about $1,000 complete, as they were in the 400-ft. sand. In the first year the investment of $43,000 was returned; in the following 54 months, when the property was sold, the profits ranged from 6 to 40 per cent. per month.

Gas Developments

Paucity Due to Leakage.—Although Illinois has proved an exceptionally rich oil producer, the gas output is disappointing. While sufficient gas is usually produced to operate with and supply the neighboring towns, not enough has been developed to warrant piping to the metropolitan markets of St. Louis and Chicago.

This paucity seems to be due to faulting, as minor faults occur that apparently have allowed more or less of the gas to escape. That the gas has been only partly preserved is shown not only by the small size of the wells, but usually by the absence of the heavy pressures that occur in other fields.

That faulting is responsible for the deficiency is verified at Centralia, where there is no gas; yet 6 miles north, at Sandoval, on the same anticline, the same sands are rich in gas; but at Centralia a fault is shown by the coal mines that has not only vented the gas, but is permitting some of the viscous oil to escape into the coal shafts.

The northern parts of the fields usually have more gas than the southern portions, which harmonizes with the faulting theory, as the faults are more numerous and heavier toward the south, from the closer proximity to the Ozark uplift.

That the oil has been so slightly affected by the faults—at least, in the lower sands—is due to its viscous nature and strong capillary adhesion as compared with the great elasticity and extreme mobility of the gas.

For the gas can move and more or less escape through minute fractures caused by faulting that are more or less impervious to the viscous oil.

Gushers.—On the opening of a new pool the gas pressure is often sufficient to cause the wells to flow intermittently for a short time, or until the pressure is relieved. The gusher type is exceptional, however, and most wells have to be pumped from the outset.

Size of Gas Wells.—Gas wells usually come in at 200,000 to 1,000,000 cu. ft. a day, rarely at 2,000,000 to 5,000,000, which for a new field is modest. There are comparatively few "dry" gas wells, as the gas generally occurs with the oil; hence when a "gasser" is found the oil usually occurs in the immediate vicinity.

Values.—The towns are supplied by local gas companies at 20c. to 30c. per 1,000 cu. ft. for domestic purposes and the gas is metered. The companies either have their own wells, or buy gas from oil producers, who have an excess, at 5c. to 10c. per 1,000 cu. ft. at the wells.

Drillers are furnished gas at a flat rate of $5 a day for the boiler and lighting.

The value of the Illinois gas output in 1912 is estimated[6] at $616,467, or about 2 per cent. of the oil value, of which 1,236,162,000 cu. ft. was sold at an average of 23.62c. for domestic use and 5,603,318,000 ft. at 7.43c. for industrial purposes.

The actual production was much larger, as the oil operators continue to waste large quantities, especially in new pools and when a flowing well comes in.

Gasoline from Gas

Few Plants.—The Illinois oil field is so young and so lucrative that thus far little attention has been paid to gas gasoline. The old wells of Pennsylvania are so small and the casing-head gas is usually so rich that the gas-gasoline revenue often exceeds that from the oil, whereas in Illinois it amounts to only 5 to 10 per cent. of the oil revenue. As the Illinois wells decline and as the gas grows richer, more attention will be given to extracting the gasoline. Only six plants are operating in eastern Illinois and compound compressors are employed to liquefy the gasoline vapors that are contained in the gas. Two grades are made, or a high-grade 70° to 80° gravity gasoline by the low-pressure cylinder and a very high-grade 80° to 95° B. fluid by the high-pressure cylinder. Both grades are usually blended with naphtha to render them safe for shipping and to reduce the heavy volatilization loss. The 90° to 95° gravity fluid is so extremely volatile that if a cupful is tossed into the air on a warm day, it will volatilize before reaching the ground.

Yield.—The gasoline yield of Illinois gas ranges from 1.5 to 2.5 gal.

[6] *Production of Natural Gas in* 1912, U. S. Geological Survey, p. 5 (1913).

per 1,000 cu. ft., and about 75 per cent. of the gas is available for returning to the gas main, if subsequently utilized.

Prices.—The gasoline is frequently retailed from the lease to automobiles at 12c. to 15c. a gallon, although large producers usually sell it to jobbers at 8c. to 10c. It has to be shipped in steel containers, as the loss and risk are too great to permit shipment in wooden barrels.

There is a keen demand for this exceptionally high-grade gasoline and the industry has a bright future that the Illinois operators should more generally appreciate.

Statistics

The data given in the following statistics were obtained from the annual *Mineral Statistics*, published by the U. S. Geological Survey, or from the *Oil City Derrick*.

Table II presents a summary of the wells drilled to Jan. 1, 1914, in Illinois, since the marked activity started in 1906. It shows a tremendous outburst of activity in 1907, when about 5,000 holes were drilled, since which there has been a steady, marked decline until 1913. The high prices for oil stimulated the drilling of many inside locations last year, where the sands had been more or less drained, which accounts for the smaller percentage of dry holes and the much lower average yield.

The average yield declined from 40.4 barrels in 1906 to 26.1 barrels in 1908, as the flush period passed in the very active shallow Crawford County district. The greater activity in the deeper but richer sands of Lawrence county reversed the usual retrogression that nearly all young fields exhibit and the average output of the new wells steadily increased up to 1912, when it averaged 67 barrels per well, which is exceptionally high for a high-grade field.

TABLE II.—*Summary of Illinois Drilling*

Year	Wells Drilled	Produced Oil		Initial Yield Barrels		Produced Gas		Dry	
		Number	Per Cent.	Total Yield	Daily Yield	Number	Per Cent.	Number	Per Cent.
1905	227	189	83.2	......	....	..	...	37	16.8
1906	3,283	2,793	85.1	113,012	40.4	..	...	490	14.9
1907	4,988	4,260	85.4	139,163	32.6	..	...	728	14.6
1908	3,574	3,019	84.5	78,960	26.1	..	...	555	15.5
1909	3,151	2,593	82.3	89,756	34.0	70	2.2	485	15.4
1910	2,149	1,681	78.2	93,256	55.8	75	3.4	393	18.3
1911	1,365	1,061	77.7	66,919	63.1	42	3.1	263	19.2
1912	1,260	980	77.8	65,686	66.6	23	1.8	257	20.4
1913	1,747	1,439	82.0	47,558	33.3	40	2.4	268	15.6
Totals	21,744	18,025	82.9	694,310	38.5			3,486	16.0

Table III gives the average initial daily yield of the wells in the producing counties of Illinois and gives an approximate idea of the relative richness of the sands. It also shows the activity in drilling inside wells in 1913 in all the counties, and the consequent drop-off in the yield.

TABLE III.—*Average Initial Daily Yield of Illinois Wells by Counties*

County	1906	1907	1908	1909	1910	1911	1912	1913
Eastern Field.—Barrels								
Clark	26.5	20.9	23.3	24.0	22.5	17.1	23.6	15.2
Coles	5.5	7.0	15.3	10.6	16.3	5.0	5.0	20.0
Crawford	66.1	34.2	23.5	25.5	27.8	26.6	23.1	17.1
Cumberland	29.9	26.0	9.8	24.3	12.5	16.7	19.0	12.0
Edgar	4.8	10.7	6.4	5.0	.....	....	....	....
Lawrence	50.6	49.2	36.2	61.5	102.7	86.8	10.5	54.0
Jasper	....	....	....	7.1	10.0	6.7	....	5.0
Wabash	....	....	....	....	....	....	50.0	39.0
Western Field.—Barrels								
Bond	....	....	....	....	25.0	....	....	....
Clinton	....	....	....	....	....	95.0	32.2	10.0
Macoupin	....	....	....	5.0	....	3.5	3.0	55.0
Marion	....	....	....	37.2	110.6	91.5	27.7	23.0
Randolph	....	....	....	72.5	....	....	....	....
State Average	40.5	32.7	26.2	34.6	55.5	63.0	67.0	33.3

TABLE IV.—*Wells Drilled in Illinois in* 1913

County	Wells Drilled	Produced Oil Per Cent.	Average Initial Daily Output Barrels	Dry Holes Per Cent
Clark (Casey)	208	81	15.2	19
Clinton (Carlyle)	19	74	10.0	26
Coles	6	67	20.0	33
Crawford (Robinson)	689	80	17.1	20
Cumberland (Siggins)	63	80	12.0	20
Lawrence (Bridgeport)	667	89	54.0	11
Macoupin (Carlinville)	9	33	55.0	67
Marion (Sandoval)	22	95	23.0	5
Wabash (Allendale)	49	50	39.0	50
Miscellaneous	15	13	12.0	87
Total	1,747	82	33.3	18

1,439 wells = 82.0 per cent. came in with an ouput of 33.3 barrels daily (average).
40 wells = 2.4 per cent. came in as gas wells.
268 wells = 15.6 per cent. came in as dry holes.

1,747 wells = 100.0 per cent. or the total wells completed in 1913.

Table IV shows that 1,747 wells were drilled in Illinois in 1913, of which 82 per cent. were oil producers that came in at an average of 33.3

barrels per day, and 2.4 per cent. were gas producers. It also shows that almost no prospecting was carried on, as only 15 holes were drilled outside of the producing fields. This insignificant effort to open up new territory was largely due to the great scarcity of drillers, who were attracted by the fierce boom in Oklahoma, where rates are higher and work was very plentiful.

Table V presents a summary of the drilling in 1913 in the States that exclusively produce high-grade oil (paraffine base). It shows their relative activity by the number of wells completed; and while the drill was unusually busy in all, it shows the extent of the unprecedented boom in Oklahoma, where over 9,000 holes were drilled. In spite of bringing in the very rich Cushing and Boston pools in Oklahoma, the average well shows a further decline to 46 barrels per day, although in the old nip-and-tuck race with Illinois for first honors in the highest average well, it leads the latter (33.3 barrels) by nearly as large a margin as Illinois with 67 barrels led Oklahoma in 1912, at 48.6 barrels.

With the exception of New York (where the average well came in at 1.8 barrels, which would be called a dry hole in Illinois), the record of 82 per cent. of the Illinois wells coming in as oil producers is the highest, as the other States range from 80 to 38 per cent.

Table V.—*Wells Drilled in the High-Grade Oil Fields in* 1913

State	Wells Drilled	Produced Oil		Initial Yield Barrels		Produced Gas		Dry	
		Number	Per Cent.	Total	Daily Average	Number	Per Cent.	Number	Per Cent.
New York...	510	443	87	807	1.8	45	9.0	22	4.0
Pennsylvania.	3,719	2,961	80	8,155	2.8	263	7.0	495	13.0
West Virginia.	2,072	1,290	62	34,287	26.6	453	22.0	329	16.0
Ohio.........	1,447	551	38	13,409	24.3	685	47.0	211	15.0
Indiana......	310	212	68	7,361	34.7	12	4.0	86	28.0
Kentucky....	211	134	64	2,310	17.0	3	1.5	74	34.5
Illinois.......	1,747	1,439	82	47,558	33.3	40	2.4	268	15.6
Kansas......	2,149	1,583	73	22,985	14.5	292	14.0	274	13.0
Oklahoma....	9,112	7,232	79	331,385	46.0	572	6.0	1,306	15.0

The richness of the Illinois fields is shown in Table V, as its high daily average production of 33.3 barrels exceeds all the other States (1.8 to 24.3 barrels) excepting Oklahoma, as previously mentioned, and Indiana (34.7 barrels); the latter State made an unprecedented record, as its wells usually come in at 10 to 20 barrels. The increase is due to the opening up of the new Sullivan County field, which adjoins Crawford county, Ill., and seems to be influenced by the same cross-anticlinal zone that passes through the latter.

Fuel Oil in the Southwest

With a Bibliography of Fuel Oil Generally

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THIS paper was prepared at the request of Capt. A. F. Lucas, Chairman of the Institute's Committee on Petroleum and Gas, as a preliminary discussion of the fuel oils which are used in the Southwest, giving their composition, uses, prices, etc. Should it afterward be found desirable, these observations may be extended over a larger area. In this connection, I suggest that samples of all kinds of fuel oils, including various tars, from all over the country, be collected and sent to some testing laboratory for examination. We would be glad to extend the facilities of the laboratory of the Bureau of Economic Geology and Technology, at the University of Texas, for this purpose, and to do the work free of all expenses. After such examinations are made and the results classified and studied, it would be possible to suggest specifications under which fuel oils should be purchased, and to arrive at some conclusions respecting the uniformity of such specifications, with due allowance for climatic and other more or less local conditions. While such specifications do not now depart from a common standard anything like as much as specifications for illuminating oils do, yet there are discrepancies which should not exist. Some of these discrepancies are of lessening importance, due to the pronounced tendency to distill every crude oil that can be distilled with profit, and to send residues into the market for fuel oil. Residues from the refineries are of a more uniform chemical composition and physical nature than many of the crude oils that go direct into the fuel market.

The lower flash-point oils are disappearing from the fuel trade and in place of them we are getting oils that do not flash below 220° F., nor burn under 320° F. In the Southwest, it has not been long since we had fuel oils that flashed as low as 110° F., and the average flash point over a considerable period was 151° F. Now we are using oil that flashes at about 30° lower than the former burning point, which was 256° F. In other words, the flash point has risen, on the average, 100°; and the burning point about 75°.

Less than two years ago the range of flash point in fuel oils brought under our observation was from 110° to 208°, a variation of nearly 100°. These same oils had a burning point from 210° to 303°, a range of nearly 100°. Within the last months, fuel oils have shown a range of flash point from 180° to 276°, and of burning point from 260° to 345°. While the range of flash and burning points in these oils is about the same in each case, taking all kinds of oil, yet the range in residuum oil is much less marked. It is easy to see that a fuel oil flashing at 110° is a dangerous oil. The U. S. Navy regulation of 200° flash point is not unreasonable. We shall recur to this matter again.

As an aid in this investigation, I have prepared a bibliography of books and articles dealing with fuel oil. The basis of these lists is the excellent Bibliography of Petroleum prepared by W. H. Dalton, L. V. Dalton, S. L. James, and E. S. Ward for the third (1913) edition of Sir Boverton Redwood's *Treatise on Petroleum*. These gentlemen listed 8,804 titles, from 1662 to 1911. I went over this list carefully and took out the titles of all books and articles referring specifically to fuel oil and added to it many titles for the years 1911–1912, and part of 1913. All of these titles were then classified under appropriate and convenient headings, so that it is now easy to see what has been published, according to subject. It is not claimed for this bibliography that it is original or complete, but it is thought that the 104 books and the 800 articles listed comprise by far the greater number of the really important books and papers. It represents the results of the reading and selection of some 10,000 titles. I would be much gratified to have this list criticised, corrected, added to or taken from. With the exception of the Russian references, which were translated for Redwood's book, the titles appear in the language in which the books or articles were written and as they are given in the Bibliography of Petroleum above referred to.

The fuel oils that now come into market in the Southwest are of two principal kinds:

1. Crude oil that cannot, under present conditions, be profitably distilled. Such oils contain the distillates which are removed in the refineries, together with the heavy, more or less asphaltic material which remains in the stills after the lighter fractions have been removed.

2. Residuum from the stills (*ostatki*, or *astatki*, of the Russian trade). This contains no light oils and is more or less asphaltic in character.

In the early days of the Texas-Louisiana oil industry a great deal of crude oil was sold as fuel and at very low prices, 20c. a barrel and even less. An analysis of a representative crude oil of that period is as follows:

Beaumont Oil

Fractions, Degrees F.	Per Cent. by Volume	Specific Gravity	Color
84.2 to 212	....	......	....
212 to 257	....	......	....
257 to 302	2.9	0.7938	Colorless
302 to 347	2.4	0.8275	Colorless
347 to 392	1.1	......	Colorless
392 to 437	3.1	0.8387	Pale amber
437 to 482	6.2	0.8590	Pale amber
482 to 527	11.8	0.8748	Straw yellow
527 to 572	15.3	0.8897	Straw yellow
572 to 617	5.8	0.8957	Straw yellow
Above 617	36.8	0.9094	Reddish brown

The color of the crude oil was reddish brown; the flash point was 120° F.; the specific gravity was 0.9103 = 24° Baumé; it contained 2.4 per cent. of sulphur; the British thermal units per pound were 19,785.

Other samples of the early Beaumont oil had a flash point of 165° F. (open cup), a viscosity of 98 at 70° F., and did not congeal at 10° below zero F. They showed less sulphur than the above analysis. The fractions yielded up to 500° F. varied from 19 to 38 per cent., according to different samples and different analysts. A flash test of 110° and a burning test of 180° are recorded, but, so far as the writer is informed, there was no flash point higher than 165° F., nor burning point higher than 200° F. The oil had a comparatively low viscosity, flowed readily, was easily handled by ordinary pumps and did not congeal at a temperature several degrees below zero, 5 to 10.

Fuel oil of this general character was supplied for several years, even after the completion of some of the refineries, and it is still marketed.

Following the completion of the refineries and the laying of pipe lines less and less crude oil was sold for fuel and more of it was distilled. The increasing demand for gasoline, naphtha, etc., consequent upon the development of the internal-combustion engine and chemical industries, was instrumental in causing a gradual shifting of the fuel-oil trade from crude oil to the residuum oil.

In the laboratory of the Bureau of Economic Geology and Technology, University of Texas, we have recently examined 12 samples of representative fuel oils from Texas and Louisiana. These oils were distilled by the Engler method, and, in addition, there were determined the color, specific gravity, viscosity, flash point, burning point, and British thermal units per pound.

The following tables show the character of these oils (analyses by S. H. Worrell and J. E. Stullken):

Analysis No.	Specific Gravity at 60° F.	Viscosity at 70° F.	Flash Point, Deg. F.	Burning Point, Deg. F.	B.t.u. per pound.
1,152	0.898 (26° B.)	2,000	248	302	19,164
1,153	0.921 (22° B.)	226	140	195	18,996
1,156	0.915 (23° B.)	204	140	167	19,040
1,157	0.940 (19° B.)	1,200	248	302	18,880
1,158	0.910 (24° B.)	204	131	156	19,080
1,159	0.898 (26° B.)	1,008	212	302	19,160
1,160	0.940 (19° B.)	1,134	158	230	18,884
1,161	0.921 (22° B.)	106	104	140	19,000
1,167	0.915 (23° B.)	151	194	266	19,028
1,168	0.927 (21° B.)	1,764	266	356	19,312
1,169	0.927 (21° B.)	270	159	257	19,312
1,170	0.940 (19° B.)	3,600	140	185	19,232

In these analyses the specific gravity varied from 0.898 (26° B.) to 0.940 (19° B.), with an average of 0.917 (22.5° B.); the viscosity varied from 106 to 3,600; the flash point varied from 104° to 248° F., with an average, if figures so far apart may be averaged, of 178° F.; the burning point varied from 140° to 356° F., with an average of 236° F. There was not a great variation in the B.t.u. and the average was 19,090.

These samples were also distilled, with the following results:

Analysis No. 1,152. *Saratoga Light Crude Oil. Color, Red-Brown*

Degrees F.		Per Cent.	Color
Below 212		None	....
212 to 302		None	....
302 to 392		None	....
392 to 482		2.5	Prime white
482 to 572		17.5	Cream white
572 to 662		7.0	Extra pale
Above 662	12.5		Lemon pale
	20.0		Orange pale
	19.5		Light red
	13.5		Dark red
		65.5	
Residue, by weight		7.5	....
		100.0	

Analysis No. 1,153. *Saratoga Heavy Crude Oil. Color, Dark Brown*

Degrees F.	Per Cent.	Color
Below 212	None	....
212 to 302	None	....
302 to 392	7.0	White
392 to 482	10.0	White
482 to 572	20.0	Cream white
572 to 662	44.0	Lemon pale
Above 662	16.0	Red
Residue, by weight	3.0	....
	100.0	

Analysis No. 1,156. *Humble Crude Oil. Color, Red-Brown*

Degrees F.		Per Cent.	Color
Below 212		None	....
212 to 302		4.0	White
302 to 392		2.5	White
392 to 482		10.0	White
482 to 572		19.0	Prime white
572 to 662		12.0	Cream white
Above 662	21.0		Extra pale
	19.5		Lemon pale
		40.5	
Residue, by weight		12.0	....
		100.0	

Analysis No. 1,157. *Welsh Crude Oil. Color, Dark Brown*

Degrees F.		Per Cent.	Color
Below 212		None	....
212 to 302		None	....
302 to 392		None	....
392 to 482		4.0	Cream white
482 to 572		22.0	Extra pale
572 to 662	60.0		Orange pale
	5.0		Light red
		65.0	
Above 662		None	....
Residue, by weight		9.0	....
		100.0	

Analysis No. 1,158. *Humble Crude Oil. Color, Red-Brown*
2,800-*ft. Sand*

Degrees F.		Per Cent.	Color
Below 212		6.0	White
212 to 302		4.5	White
302 to 392		17.0	White
392 to 482		3.0	Prime white
482 to 572		14.0	Cream white
572 to 662		9.0	Extra pale
	15.0		Lemon pale
Above 662	20.0		Orange pale
	6.0		Light red
		40.1	
Residue, by weight		5.5	....
		100.0	

Analysis No. 1,159. *Electra Residuum Oil. Color, Red-Brown*

Degrees F.		Per Cent.	Color
Below 212		None	....
212 to 302		None	....
302 to 392		1.0	White
392 to 482		1.0	White
482 to 572		11.0	Prime white
572 to 662		5.5	Cream white
Above 662	18.5		Extra pale
	17.0		Lemon pale
	16.0		Orange pale
	16.0		Light red
	5.5		Dark red
		73.0	
Residue, by weight		8.5	....
		100.0	

Analysis No. 1,160. *Sour Lake Crude Oil. Color, Red-Brown*

Degrees F.		Per Cent.	Color
Below 212		None	....
212 to 302		None	....
302 to 392		None	....
392 to 482		11.0	Cream white
482 to 572		23.0	Extra pale
572 to 662	20.0		Lemon pale
	19.0		Light red
		39.0	
Above 662		19.0	Red
Residue, by weight		8.0	....
		100.0	

Analysis No. 1,161. *Humble Crude Oil. Color, Red-Brown*
1,200-ft. Sand

Degrees F.	Per Cent.	Color
Below 212	None	....
212 to 302	11.0	Cream white
302 to 392	10.0	Extra pale
392 to 482	15.0	Extra pale
482 to 572	38.0	Orange pale
572 to 662	20.0	Orange pale
Above 662	4.0	Red
Residue, by weight	2.0	....
	100.0	

Analysis No. 1,167. *Markham Crude Oil. Color, Light-Brown.*

Degrees F.		Per Cent.	Color
Below 212		None	....
212 to 302		None	....
302 to 392		5.0	White
392 to 482		18.0	White
482 to 572	20.0		White
	8.0		Extra pale
		28.0	
572 to 662	19.0		Extra pale
	20.0		Lemon pale
	4.0		Orange pale
		43.0	
Above 662		5.0	Red
Residue, by weight		1.0	....
		100.0	

Analysis No. 1,168. *Caddo Heavy Crude Oil. Color, Dark Red-Brown*

Degrees F.		Per Cent.	Color
Below 212		None	....
212 to 302		None	....
302 to 392		None	....
392 to 482		8.0	White
482 to 572		28.0	Extra pale
572 to 662		13.0	Lemon pale
Above 662	23.0		Greenish tinge
	14.0		Light red
	6.0		Dark red
		43.0	
Residue, by weight		8.0	....
		100.0	

Analysis No. 1,169. *Vinton Crude Oil. Color, Red-Brown*

Degrees F.		Per Cent.	Color
Below 212		None	....
212 to 302		None	....
302 to 392		3.5	White
392 to 482		11.0	White
482 to 572		21.0	White
572 to 662	21.0		Cream white
	19.5		Extra pale
		40.5	
Above 662	20.0		Light red
	3.0		Red
		23.0	
Residue, by weight		1.0	....
		100.0	

Analysis No. 1,170. *Mexican Crude Oil. Color, Black*

Degrees F.		Per Cent.	Color
Below 212		None	....
212 to 302		None	....
302 to 392		8.0	White
392 to 482		6.0	White
482 to 572		14.0	Extra pale
572 to 662	20.0		Light red
	26.0		Red
		46.0	
Above 662		8.0	....
Residue, by weight		18.0	....
		100.0	

It is to be observed from these analyses:

1. The oil of the lowest flash point, 104° F., had also the lowest viscosity, 106. Up to 482° F. (250° C.), it yielded 36 per cent. of distillates, and left but little residue in the still. The burning point of this oil was 140° F. This is not a safe oil for fuel purposes, the flash point and burning point being entirely too low.

2. The oil of the highest flash point, 266° F., had a high viscosity, 1,764. Up to 482° F., it yielded 8.0 per cent. of distillates, and left 8 per cent. of residue in the still. The burning point of this oil was 356° F. This is a very safe oil for fuel purposes; but, on account of its high viscosity, it will have to be handled through larger pipes and with special pumps.

3. The oil of a medium flash point, viz., 194° F., had a comparatively low viscosity, 151. Up to 482° F., it yielded 23 per cent. of distillates. Its burning point was 266° F. While this oil, in respect of its flash point, would not meet the requirements of the U. S. Navy, 200° F., yet it is a safe fuel.

4. Out of the 12 samples examined, there were but four that showed a flash point above 200° F. Of the remaining eight, one flashed between 190° and 200°; two between 150° and 160°; three between 140° and 150°; one between 130° and 140°; and one between 100° and 110°. If we accept the Navy specification as to flash point, two-thirds of these oils would be rejected, and yet they are representative fuel oils, sold and used in large quantities throughout the Southwest. So far as the writer is informed, no serious catastrophe has occurred from the use of any of these oils, even those of lowest flash point.

In order to elucidate this matter further, I give the results of the examination of 31 samples of fuel oil tested in our laboratory for the Purchasing Agent of the State of Texas, from Nov. 26, 1912, to Jan. 22, 1914. The State of Texas maintains a Purchasing Agent, whose duty

it is to secure supplies for the charitable institutions. All of the fuels are analyzed in our laboratory regularly, the samples being taken at the points of consumption under instructions from this official. It is but fair to say that we do not have charge of the sampling, but we do advise the State Purchasing Agent how the samples should be taken. The examination of these samples shows (analyses by S. H. Worrell and J. E. Stullken):

	From	To	Average
Specific gravity	0.868 (31° B.)	0.931 (21° B.)	0 898 (26° B.)
Viscosity at 70° F.	204	1,026	548
Flash point	110	291	203
Burning point	180	350	277
B.t.u. per pound	18,964	19,500	19,173

There has been a marked change in the character of fuel oils examined for the State Purchasing Agent since November, 1912, with respect to flash and burning points. During 1912–1913, we examined 19 samples. These showed:

	From	To	Average
Specific gravity	0.868 (31° B.)	0.931 (20° B.)	0.898
Flash point	110	218	151
Burning point	180	276	221

Of 12 samples examined for flash point, only two came up to the Navy requirements of 200° F. One sample gave between 190° and 200°; one sample between 180° and 190°; one between 140° and 150°; one between 130° and 140°; five between 120° and 130°; and one between 100° and 110°.

Beginning in the fall of 1913 and continuing through the winter deliveries, 12 samples of fuel oil, under contracts for the State, showed the following:

	From	To	Average
Specific gravity	0.892 (27° B.)	0.904 (25° B.)	0.90 (25° B.)
Viscosity	204	1,026	548
Flash point	210	303	250
Burning point	260	350	324

As compared with the quality in 1912 and the early part of 1913, we observe that the flash point increased from 110° to 210° F., the average increasing from 151° to 250°; the burning point increased from 180° to 260°, the average increasing from 221° to 324°. No viscosity determinations were made on the earlier samples.

Of these 12 samples, not one of them flashed as low as 200° F., and the average of the entire lot was 250°. These samples were taken from actual deliveries at points of consumption and are not company samples at all.

Every one of these samples represents a safe fuel oil, whereas, of the former lot only two out of twelve, or 16.6 per cent., are to be considered as safe, from the standpoint of flashing.

During the last months there has been some complaint from fuel-oil consumers as to the quality of the oil. In nearly every case that has been investigated, the trouble was found to be in the methods of handling, in the pumps and in the burners. In one particular case the oil was pumped about 1¼ miles from the railroad siding to the storage tanks at the boilers. It was handled with difficulty. The pipe was too small and the pumps were not designed to handle a heavy, viscid oil.

In another case, the consumer said that he was compelled to add about 300 gal. of kerosene to his fuel oil in order to get it through the pipes to the burners, by gravity. What the insurance company would have said to him is another matter! But neither the insurance companies nor the municipal authorities are supposed to know everything and there is an old, but questionable, statement, to the effect that what you don't know won't hurt you.

Water in Fuel Oil

I approach this subject with some hesitancy, for I am aware of the confusion attending it. The accurate determination of water in heavy oils is a matter of considerable difficulty, and it is doubtful if any of the methods now proposed is reliable in every case. Of course, there should not be water in fuel oil, but, equally of course, it is sometimes present. It is gratifying to be able to say that of the 50 odd commercial samples of fuel oil examined in our laboratory during the last two years, only two contained appreciable amounts of water. Of these two, however, one contained 20 per cent., and the other 5 per cent. Neither of these oils was a very heavy oil, so that we were able to determine the water with a fair degree of accuracy.

We are now trying out a number of methods for the determination of water in heavy crude oils and in residuum oils and hope to be able to report on this matter later. As far as we have progressed, however, we are able to say that the gasoline method, as adopted by the U. S. Navy, does not apply to some of the very heavy oils with which we have to deal.

Residuum oils can contain water only if it is purposely added or if rain water, etc., gets into the tank cars or reservoirs.

Dirt, Sand, Sediment, etc.

Practically all of the oils that we have examined were commercially free from sand, sediment, etc. One complaint that reached us was found to be due to an insufficient pipe line and to inadequate pumps and burners, not to the quality of the oil. If the well casing is not properly set, or if there is a break in the casing, opportunity is given for the intake of dirt, etc., but we have not found that the fuel oils are dirty oils. One consumer complained that his oil was dirty because he could write his name in the dirt that was on top of the oil. This complaint was not found to be well based.

Sulphur

We have not examined many fuel oils for sulphur. As a rule, this ingredient is not included in specifications, and is not ordinarily determined. In some fuel oils the sulphur may be as high as 1 per cent., but the average is probably below 0.75 per cent.

Viscosity

Considering the advent of very heavy, viscid oils into the fuel trade, the degree of viscosity should always be specified. In the U. S. Navy it is required that fuel oil shall flow freely from a round orifice of ½ in. under a head of 2 ft., at a temperature of 40° F. This is a severe requirement and should be modified. A better plan would be to require that the oil shall flow through an orifice of given size at the rate of so many gallons, or fractions thereof, per unit of time, at a temperature of 60° F., and under a given head. Many of our best fuel oils would be excluded under the present specifications. The expression "shall flow freely and in a continuous stream" is entirely too vague. A temperature of 40° F. is too severe a requirement, considering that the flash point is placed at the minimum of 200° F.

We determined the specific gravity at 60° F. and the viscosity at 70° F., in 24 samples. The results were as follows—specific gravity, upper figures; viscosity, lower figures:

0.892	0.898	0.902	0.904	0.910	0.915	0.921	0.927	0.940
250	444	1,026	204	204	151	106	270	1,134
285	636		384		204	226	1,764	1,200
	840		560					3,600
	1,008		564					
	2,000		618					
			768					

According to these results, there is no connection between the specific gravity and the viscosity. While it is true that the heaviest oil had the

highest viscosity, yet one of the lighter oils had a viscosity greater than two of the samples of the heaviest oil. The lowest viscosities observed, 106 and 226, were in a heavy oil, specific gravity 0.921. The lightest oil did not have the lowest viscosity.

There are heavy liquids that are not viscous and there are viscous liquids whose viscosity is exceeded by that of lighter liquids.

Viscosity arises from the mutual attraction of the molecules. An increase of temperature diminishes it and a decrease of temperature increases it. For the easily flowing oils we should employ the term *mobility*, as this is the opposite of *viscosity*. Just where the line of separation should be drawn, for fuel oils, I am not now prepared to say, but would venture to suggest that it be made a subject of investigation by the Institute's Committee on Petroleum and Gas. With such a wide range in fuel oils, 106 to 3,600, in what is termed "viscosity," it would appear that there is urgent need of a new nomenclature. There are five principal elements that enter into this matter:

1. Time.
2. Amount of oil.
3. Temperature.
4. Size and condition of orifice.
5. Head.

The term "viscosity" should relate to the *time* required for a given *amount* of oil at a given *temperature* to flow through a given *orifice* under a given *head*. This would clarify a much-troubled subject.

In *Technical Paper No.* 3 of the U. S. Bureau of Mines, Washington, 1911, Irving C. Allen proposes the following specifications for fuel oil to be purchased by the government:

(1) In determining the award of a contract, consideration will be given to the quality of the fuel offered by the bidders, as well as the price, and should it appear to be to the best interest of the Government to award a contract at a higher price than that named in the lowest bid or bids received, the contract will be so awarded.

(2) Fuel oil should be either a natural homogeneous oil or a homogeneous residue from a natural oil; if the latter, all constituents having a low flash point should have been removed by distillation; it should not be composed of a light oil and a heavy residue mixed in such proportions as to give the density desired.

(3) It should not have been distilled at a temperature high enough to burn it, nor at a temperature so high that flecks of carbonaceous matter began to separate.

(4) It should not flash below 60° C. (140° F.) in a closed Abel-Pensky or Pensky-Martens tester.

(5) Its specific gravity should range from 0.85 to 0.96 at 15° C. (59° F.); the oil should be rejected if its specific gravity is above 0.97 at that temperature.

(6) It should be mobile, free from solid or semisolid bodies, and should flow readily, at ordinary atmospheric temperatures and under a head of 1 ft. of oil, through a 4-in. pipe 10 ft. in length.

(7) It should not congeal nor become too sluggish to flow at 0° C. (32° F.).

(8) It should have a calorific value of not less than 10,000 calories per gram (18,000

B.t.u. per pound); 10,250 calories to be the standard. A bonus is to be paid or a penalty deducted according to the method stated under section 21, as the fuel oil delivered is above or below this standard.

(9) It should be rejected if it contains more than 2 per cent. water.

(10) It should be rejected if it contains more than 1 per cent. sulphur.

(11) It should not contain more than a trace of sand, clay, or dirt.

The specifications for fuel oil for the U. S. Navy are as follows:

1. Fuel oil shall be a petroleum of best quality, free from grit, acid, fibrous and other foreign matter likely to clog or injure the burners or valves.

2. The unit of quantity to be a gallon of 231 cu. in. at a standard temperature of 60° F. For every variation of 10° F. from the standard, one-half of 1 per cent. shall be added to or deducted from the measured or gauged quantity for correction.

3. Sulphur in the oil must not exceed three-fourths of 1 per cent. by weight.

4. Free water and sediment in the oil shown by gasoline test must not exceed 1 per cent. by volume. The gasoline test shall be made as follows:

5. Samples taken at random should be thoroughly shaken and mixed; then 50 c.c. of sample placed in a 100-cm. graduated glass cylinder. An equal quantity of not less than 68° gasoline should be mixed with the sample in the graduated glass; the combined mixture of oil and gasoline should then be thoroughly shaken and mixed and allowed to stand not less than 6 hrs., when percentage of water and sediment will be taken by the inspector.

6. The oil shall not flash at a temperature less than 200° F., the test to be made by the Abel or Pensky-Martens closed cup method.

7. The oil shall have a gravity Baumé not greater than 30° at 60° F., determined from an average sample.

8. The oil shall flow freely and in a continuous stream through a $\frac{1}{2}$-in. circular hole, under a 2-ft. head at a temperature of 40° F. Oil that fails to flow freely and in the required quantities to pump suctions, pass through pumps, piping and burners at a temperature of 40° F. may be rejected.

9. The oil shall have a calorific value not under 144,000 B.t.u. per gallon, to be taken from an average sample or samples of the product as delivered, or made before delivery. In determining this value, the bomb calorimeter shall be used to determine the B.t.u. per pound from which the B.t.u. per gallon shall be calculated by using 8.331 lb. of distilled water per gallon at 60° F. and the specified gravity of the oil as determined by the Baumé test at same temperature.

Mr. Irving recommends a flash point not below 140° F., the Navy specifications a flash point not below 200° F. Mr. Irving recommends that the oil should be so mobile as to flow readily, at ordinary atmospheric temperatures and under a head of 1 ft. of oil, through a 4-in. pipe 10 ft. in length. The Navy calls for an oil that shall flow freely and in a continuous stream through a $\frac{1}{2}$-in. circular hole, under a 2-ft. head, at a temperature of 40° F.

Mr. Irving recommends that the oil should not contain more than 2 per cent. of water or 1 per cent. of sulphur, or more than a trace of sand, clay, or dirt. The Navy allows 1 per cent., by volume, of free water *and* sediment and allows not over 0.75 per cent. of sulphur. It is probable that most of the heavy oils now sold in the Southwest would have no special difficulty in meeting any of these suggestions or specifications, with the exception of the mobile and viscosity tests. I have not had

time or opportunity for inquiring into the specifications for fuel oil as adopted by foreign governments, but this will be done as soon as possible.

Production

During the last six years, in which there has been so great a development of the fuel-oil industry, the total production of crude petroleum in the United States was 1,179,823,421 barrels of 42 gal. Of this amount, the Southwest produced as follows:

	Barrels
Louisiana	40,673,880
Oklahoma	296,707,537
Texas	63,225,422
	400,606,839

Or about 34 per cent. of the total.

It is not known how much of the oil produced in these States was sold, for fuel purposes, as crude oil, or how much was first sent to the refineries and afterward sold. Such statistics as have been collected are incomplete and, therefore, misleading. Furthermore, not all of the residues from the stills goes into the fuel market, for considerable quantities are used for roofing, for road surfacing, for bitulithic purposes, etc.

Imports

The value of the imports for consumption of petroleum during the last five years is reported by the U. S. Bureau of Foreign and Domestic Commerce as follows:

1908	$607,658
1909	197,023
1910	1,398,861
1911	2,410,884
1912	6,082,881
	$10,697,307

The imports of Mexican crude and residuum have been as follows (*Fuel Oil Journal*, vol. v, No. 2, pp. 7, 8, Feb., 1914):

In 1912 the imports were 6,500,000 barrels, and in 1913, with the exception of December returns from Port Tampa and Jacksonville, Florida, were 16,360,779 barrels. By ports the figures are:

	Barrels	Value
Galveston	3,130,497	$1,702,546
Sabine	2,490,613	1,328,529
New Orleans	2,318,297	1,385,898
New York	2,155,091	2,028,335
Port Arthur	1,501,524	856,736
Corpus Christi and Port Aransas	1,317,049	398,452
Tampa	972,550	605,195
Baltimore	914,469	557,628
Philadelphia	634,725	341,596
Jacksonville	295,570	173,720
Providence	114,000	55,378
Missing returns and miscellaneous	516,394	....
	16,360,779	$9,434,013

Exports—Territorial

The shipments of crude petroleum to Alaska, the Hawaiian Islands, and Porto Rico, during the years named, were as follows, in barrels of 42 gal.:

	Alaska	Hawaiian Islands	Porto Rico
1906	64,000	......	......
1907	216,770	926,581	.....
1908	283,128	1,136,900	5,937
1909	334,283	1,034,797	1,211
1910	448,467	1,288,502	2,080
1911	431,959	1,114,084	12,299
1912	79,144	917,238	602
Total	1,857,751	6,418,102	22,128

Exports

The exports of crude oil during the last four fiscal years, ending June 30, were as follows, in barrels of 42 gal.:

	1909	1910	1911	1912
To Europe	1,619,037	542,233	797,102	1,226,228
To North America	1,989,612	2,755,732	2,949,956	3,183,372
To South America	242,448	722,706	661,764	543,794
To Japan	192,915	....	....	....
Total	4,044,012	4,020,671	4,408,822	4,953,394

During these same years, the exports of residuum, in barrels of 42 gal., were as follows:

	1909	1910	1911	1912
Europe	92,070,389	112,792,362	102,430,883	111,321,764
North America	10,962,529	10,742,492	15,708,381	30,443,892
All others	155,115	520,924	5,258,924	26,573,822
Total	103,188,033	124,055,778	123,408,188	168,339,478

The exports of crude oil during these years remained fairly steady, but there was a considerable increase in the exportation of residuum, amounting to about 63 per cent. as between 1909 and 1912.

Prices

The prices of fuel oil in the Southwest as given by the *Fuel Oil Journal*, Houston, are as follows, at different points:

During the last three months of 1911, prices at Texas points varied from 70c. to 75c. a barrel, and at Louisiana points, from 63c. to 80c., the latter price maintaining for Mississippi river points.

During 1912, prices at Texas points were quoted at 70c. in January and 95c. to $1 in December. At Louisiana points prices varied from 63c. in January to $1 in December. In Oklahoma (Tulsa), they varied from 60c. in January to $1.15 in December.

In 1913, Texas prices opened at $1.10 to $1.26, and advanced during the year to $1.18 and $1.30. At Louisiana points the prices varied from $1 to $1.25, and in Oklahoma (Tulsa) quotations in January were from $1 to $1.25, declining to 75c. to 85c. in December. During 1913, the prices of Mexican crude at Texas ports ranged from $1.05 to $1.20.

During the last two years there has been a stiffening of prices—viz., from 70c. to $1.30 a barrel.

In the year 1900, just preceding the discovery of the Beaumont oil field, the average value of crude petroleum in Texas was $1.04 a barrel. In 1901 it was 29c., and in 1902 it was 22c., the lowest average price ever reached in the State.

The change in the conditions surrounding the industry is well shown in the fact that the 28,136,189 barrels of crude oil produced in Texas in 1905 were worth $7,552,262, or 27c. per barrel, while the 11,735,057 barrels produced in 1912 were worth $8,852,713, or 75c. a barrel. Residuum oil is now selling 30 per cent. higher than crude oil in 1900, and about 170 per cent. higher than crude oil in 1902.

In 1907, the production of crude oil in Oklahoma was 43,524,128 barrels, valued at $17,513,524, or 40c. a barrel. In 1912, the production was 51,427,071 barrels, valued at $34,672,604, or 67c. a barrel.

In 1905, the production of crude oil in Louisiana was 8,910,416 barrels, valued at $1,601,325, or 18c. a barrel. In 1912, the production was 9,263,439 barrels, valued at $7,023,827, or 75c. a barrel.

The production of what is known as the Gulf oil field (coastal Louisiana and coastal Texas) reached its maximum in 1905, with 36,526,323 barrels. In 1912, the production was 8,545,018 barrels.

These figures would seem to indicate that these oils are now being distilled for the recovery of the lighter oils and the increase in the number of refineries substantiates this view.

It is not possible, at this time, to state just what proportion of fuel oil is crude oil, but it is certainly much less than it was a few years ago, and is likely to decrease in the future, insofar as concerns the Southwest.

With the exception of the crude oil imported from Mexico, a large proportion of the fuel oil used in the Southwest is residuum from the refineries. Just how much is used, we do not know, for the statistics to hand cover only the use by railroads, and even these are incomplete for the area involved.

Dr. David T. Day, in *Mineral Resources of the United States*, U. S. Geological Survey, 1912, gives a table to show the consumption of fuel oil by the railroads of the United States, from 1906 to 1912, inclusive. This table is as follows:

Consumption of Fuel Oil by the Railroads of the United States, 1906–1912.

Year	Length of lines operated with oil. Miles	Quantity of oil consumed. Barrels	Total mileage made by engines	Average no. of miles per barrel of oil
1906	....	15,577,677	....	....
1907	13,573	18,849,803	74,079,726	3.93
1908	15,474	16,870,882	64,279,509	3.81
1909	17,676	19,905,335	72,918,118	3.66
1910	22,709	23,817,346	89,107,883	3.74
1911	30,039	29,748,845	109,680,976	3.69
1912	28,451	33,605,598	121,393,228	3.61
Total and average...	127,922	158,375,486	531,459,440	3.74

Dr. Day gives a list of 48 railroads (and systems) that used fuel oil in 1912, and of these 23 are in the Southwest.

According to the *Fuel Oil Journal* (vol. v, No. 2, pp. 66 to 68, Feb., 1914) the consumption of fuel oil by the railroads in Texas and Louisiana in 1913 was 11,148,254 barrels, as follows:

	Barrels
Southern Pacific	4,455,749
Gulf, Colorado & Santa Fé	2,342,703
Kansas City Southern	922,191
San Antonio & Aransas Pass	703,145
Frisco Lines	513,912
Trinity & Brazos Valley	409,459
Houston Belt & Terminal	104,240
All others	1,696,155
	11,148,254

In 1913, the Southern Pacific imported 1,784,143 barrels of Mexican crude for its own use as fuel.

Dr. Day states that the estimated consumption of fuel oil by railroads and for other industrial purposes, in California, in 1912, was 65,000,000 barrels. He also states that during the year 1912, the U. S. Navy used 21,000,000 gal. of fuel oil and that the consumption for 1913 will probably be 30,000,000 gal.

The President of the United States has set aside about 100 square miles of oil-producing land in the Elk Hills and Buena Vista fields, California, as a naval petroleum reserve. This reserve has an estimated capacity of 250,000,000 barrels.

For the U. S. Navy, tank storage is provided as follows:

	Barrels
Boston	36,000
Melville, R. I.	36,000
Norfolk	36,000
Charleston	36,000
Key West	36,000
Guantanamo, Cuba	223,000
Pearl Harbor, H. I.	200,000
	603,000

It is also stated that storage tanks are to be established at New York, San Francisco, San Diego, Puget Sound, Guam, and Cavite. At the Philadelphia Navy Yard there is maintained a well-equipped fuel-oil testing plant, where evaporative tests with various burners and boilers are conducted and instruction is given to the officers and men.

Bibliography of Fuel Oil

(Prepared from the Bibliography of Petroleum, in Sir Boverton Redwood's *Treatise on Petroleum,* 1913, with many additions)

Articles and Papers

Boilers

Action of Oil on

Denton, James E.—A Test on Beaumont, Texas, Oil. Pub. in *Bull. No.* 3, *Univ. Tex. Min. Surv.*, May, 1902.

Ienisch, H. Kh.—Action of Fuel Oil on Boilers. *Zap. Imp. Russk. Tekhn.*, g. xii, otd. 1, pp. 40–54. 1878.

Efficiency of

Clarke, F. T.—High Boiler Efficiency with Oil Fuel. *Power*, vol. xxxiii, 1911, pp. 720–723.

Menzin, A. L.—Performance of a 45-h.p. Boiler with Oil Fuel. *Eng. News,* May 29, 1913, p. 1125.

Rosok, T. A.—Turbine Station of the Bisbee Improvement Company, Arizona. (Results of oil-burning plant.) *Electr. Wld.*, vol. lvi, pp. 661–664. 1910.

Schpakovski.—Comparative Value for Steam Boilers of Coal, Turpentine and Petroleum. *Morsk. Sbrn.*, 1866, pp. 173–180.

Strohm, R. T.—Oil Fuel for Steam Boiler. *Mech. Wld.*, Nov. 21, 1913.

WIELAND, C. F.—Comparative Evaporative Values of Coal and Oil. *Trans. Am. Soc. Mech. Eng.*, vol. xxxiii, pp. 872–876. 1911.

Locomotive

ASTON, R. GODFREY.—Oil-burning Locomotives on the Tehuantepec National Railroad of Mexico. *Inst. Mech. Engrs.*, Dec. 15, 1911. *Iron and Coal Tr. Rev.*, Dec. 22, 1911. *Canadian Engr.*, May 16, 1912.

BOGATCHEV, V. I.—Comparison of Petroleum and Wood as Railway Fuel. *Zap. Kavk. Otd. Russk. Tekhn. Obsch.*, t. iii, p. 251. 1871.

Engineer, London.—The "Closed Circuit" Crude Oil Locomotive. Jan. 12, 1912.

FITZ, J.—Das Rohöl als Heizmaterial für Locomotiven. *Naptha*, bd. xv, pp. 485–488. 1907.

FRIESSE, W.—Rohes Petroleum als Brennmaterial für Locomotiven. *Polyt. J'l*, bd. ccxxv, p. 131. 1877.

———.—Erdolfeuerung für Locomotiven. *Polyt. J'l*, bd. cclxxxvii, pp. 30–31. 1893.

GREAVEN, L.—Petroleum Fuel in Locomotives on the Tehuantepec National Railroad of Mexico. *Proc. Inst. Mech. Eng.*, 1906, pp. 265–312.

HOLDEN, JAMES.—Notes on the Application of Liquid Fuel to the Engines of the Great Eastern Ry. *Inst. Civ. Engrs.*, No. 3937.

HOLLOWAY, B. C.—The Use of Oil Fuel on Railways. *Petrol. Wld.*, March, 1913, p. 103.

MCFARLAND, H. B.—Oil-burning on Freight Locomotives. *Cassier's Mag.*, vol. xxxviii, pp. 610–617. 1910.

MCINTOSH, J. F.—Locomotives for the Caledonian Railway Fitted for Burning Oil. *Engineering*, April 12, 1912. Holden Liquid Fuel Injectors.

Mechanical Engineer.—1,000 B.H.P. Crude Oil Locomotive. (Dunlop adiabatic closed circuit air transmission.) Jan. 19, 1912.

Mining and Engineering World.—Railroads operated by Crude Oil. May 31, 1913, p. 1034.

Railway and Engineering Review.—Oil-burning Switching Locomotives for the Balto. & Ohio R. R. Dec. 28, 1912.

Railway Master Mechanic.—Oil-burning Locomotives. June, 1912.

RYAN, J. F.—Oil Fuel. Discussion. *Proc. S.* and *S. W. Ry. Club*, Sept., 1912.

SAINTE-CLAIRE DEVILLE, H.—Emploi de l'huile de pétrole pour le chauffage des locomotives. *Ann. Sci. Ind.*, t. xiv, pp. 89–92. 1870.

——— AND DIEUDONNÉ, C.—De l'emploi industriel des huiles minérales pour le chauffage des machines et en particular des machines locomotives. *Compt. Rend.*, t. lxix, pp. 933–938. 1869.

SHEEDY, P.—The Use of Fuel Oil on the Southern Pacific Railroad. *Amer. Eng. R. R. J'l*, vol. lxxv, pp. 207–209. 1902.

STEWART, J. L.—On the Use of Petroleum as Fuel in Steamships and Locomotives, Based on Its Employment in that Way on the Caspian Sea and in the Trans-Caspian Region. *J'l Roy. United Serv. Inst.*, vol. xxx, pp. 927–949, pl. xxv. 1886.

STILLMAN, H.—Locomotive Practice in the Use of Fuel Oils. *Trans. Am. Soc. Mech. Eng.*, vol. xxxiii, pp. 887–896. 1911.

SUSSMAN, L.—Ueber Oelfeuerung für Locomotiven. *Ann. Gewerbe Bauw.*, bd. lxvi, pp. 234–237; bd. lxvi, pp. 12–16. 1910.

URQUHART, T.—On the Compounding of Locomotives Burning Petroleum Refuse in Russia. *Proc. Inst. Mech. Eng.*, 1890, pp. 47–111, pls. 1–31.

———.—Ueber die Benutzung der Petroleum-Rückstände als Brennmaterial für Locomotive-Feuerung. *Organ Eisenbahnw.*, n.f., bd. xxii, pp. 78–79, 113–118; bd. xxiii, pp. 176–177. 1885, 1886.

———.—Petroleum Firing versus Anthracite on Gryazi-Tsaritsin Railway, 1885.

———.—On the Use of Petroleum Refuse as Fuel in Locomotive Engines. *Proc. Inst. Mech. Eng.*, 1884, pp. 272–330; 1889, pp. 36–84.

———.—Apparatus for Burning Crude Petroleum in Locomotives. *Engineering*, vol. xxiii, p. 9. 1877.

VEITH, A.—Mineral Oil Residue Fuel for Locomotives. *Vasut. Hajoz. Hetilap.*, eok. iii, Nos. 26–27. 1901.

WATERS, A. L.—Consumption of Fuel Oil by Railroads. *Min. and Eng. Wld.*, Oct. 25, 1913.

WISPEK, P.—Oil Fuel on a State Railway. *Pet. Wld.*, vol. viii, pp. 133–136. 1911.

Marine

BUERK.—Petroleum as a Fuel at Sea. *Iron Age,* 1878, No. 24, p. 2.

BRESLEY, C.—Die Verwendung flüssiger Heizstoffe für Schiffskessel. *Zeitschr. Ver. deutsch. Ing.,* bd. xxxi. 1887.

CARMICHAEL, W. V.—Liquid Fuel in Ocean Steamers. Papers Shipmaster's Soc., No. 9, 1891.

CHABRIE.—Substitution du Pétrole an Charbon pour la Propulsion des Navires. *Journ. Petrol.,* t. x, p. 227. 1910.

CHURCH, A. T.—Notes on Fuel Oil and Its Combustion. *J'l Am. Soc. Naval Eng.,* vol. xxiii, 1911, pp. 795–831.

CLARK, N. B.—Petroleum as a Source of Emergency Power for Warships. *Proc. U. S. Nav. Inst.,* vol. ix, pp. 798–802. 1883.

DOMOJIROV, A.—Liquid Fuel for Ships. *Morsk. Sborn.,* No. 1, pp. 127–155. 1884.

DYSON, C. W.—Oil Fuel for Destroyers and Battleships. (Abst. paper before Soc. Nav. Archit. and Mar. Engrs.) *Power,* Feb. 4, 1913.

EDWARDS, J. R.—Liquid Fuel for Naval Purposes. *J'l Am. Soc. Naval Eng.,* vol. vii, pp. 744–764. 1895.

Engineer, London.—The Shallow Draught Steamer Comte de Flandre (Congo river). Dec. 27, 1912.

———.—Oil Fuel in the Royal Navy. July 25, 1913.

Engineering.—The Wallsend-Howden System of Oil-Burning in Marine Boilers. July 25, 1913.

FLANNERY, J. F.—On Liquid Fuels for Ships. *Trans. Inst. Naval Archt.,* vol. xliv, pp. 53–75, pls. iii, iv. 1902.

FUMANTI, GIULIO.—Boilers Fired with Liquid Fuel. (Trans. of paper read at Rome, Italy, Nov. 12, 1912, tests made for the Italian Navy.) *Engineering,* Feb. 2, 1912.

GOODENOUGH, W. J.—Memorandum Regarding Fuel Oil aboard Ships. *Marine Engineering,* vol. viii, pp. 4–6. 1903.

HENWOOD, E. N.—Liquid Fuel. *Marine Eng.,* vol. viii, pp. 24–25. 1886.

HOPPS, J. H.—Marine Use of Fuel Oil. *J'l Am. Soc. Mech. Eng.,* vol. xxxiii, pp. 896–903. 1911.

HUME, G.—Oil Fuel on Shipboard. *Trans. Inst. Marine Eng.,* vol. xix, No. 137, p. 46, pl. 1907.

IENISCH, H. KH.—Oil Fuel for Steamers on the Caspian Sea. *Morsk. Sborn.,* 1876, No. 8, pp. 1–29.

KAMENSKI.—Petroleum Residues as Fuel for Steamship Boilers *Zap. Imp. Russk. Tekhn. Obsch.,* g. iv, otd. 2, pp. 452–456, pl. 1870.

KNAB, CH.—Notice sur l'emploi des combustibles de l'huile minérale pour le chauffage des navires à vapeur. *Ann. Gén. Civil,* t. vii, pp. 305–321. 1868.

LAING, A.—Oil-burning on Board Ship. *Cassier's Mag.,* vol. xxxv, pp. 141–150. 1909.

LOVEKIN, L. D.—Notes on the Burning of Liquid Fuel. *J'l Am. Soc. Naval Engrs.,* vol. xxiii, pp. 221–247. 1911.

MAGNIN, J.—Le pétrole dans la Marine. *J'l Petrol.,* t. viii, pp. 225–228, 247. 1907.

Mining and Engineering World.—Oil for Water Navigation. Nov. 8, 1913.

MORPURGO, G.—Ueber die Anwendung des flüssigen Brennstoffes "Liquid Fuel" als Brennmaterial für die Schiffe. *Oesterr. Chem. Ztg.,* n.f., bd. v, pp. 553–555. 1902.

ORDE, E. L.—Liquid Fuel for Steamships. *Proc. Inst. Mech. Eng.,* 1902, pp. 417–435, pls. 42–46.

PARKER, W.—On the Progress and Development of Marine Engineering. *Trans. Inst. Naval Archt.,* vol. xxviii, pp. 125–146. 1887.

PEABODY, E. H.—Oil Fuel. *J'l Am. Soc. Naval Eng.,* vol. xxiii, pp. 489–499. 1911.

Petroleum Wld.—British Battleship "Queen Elizabeth," shaft h.p. 50,000; displacement 27,500 tons. First of its class. London, Nov., 1913.

PRAETORIUS, DR.—Beitrag zur Geschichte der Entwickelung der Feuerung mit flüssigen Brennstoffen auf Schiffen. Serial. *Schiffbau,* March 12, 1913.

RAVENSWORTH, EARL.—Presidential Address. *Trans. Inst. Naval Archt.,* vol. xxvii, pp. 27–36. 1886.

RIGG, E. H.—Notes on Fuel Economy as Influenced by Ship Design. *Soc. Nav. Archts. and Mar. Engrs.,* Nov. 21, 1912.

SAMUEL, M.—President's Address. *Trans. Inst. Marine Eng.,* vol. xvii, pp. 235–245. 1906.

SELWYN, J. H.—Further Information on the Employment of Mineral Oils as Fuel for Steamships. *J'l Roy. United Serv. Inst.*, vol. xii, pp. 28–43, pl. II. 1868.
———.—On Liquid Fuel. *Trans. Inst. Naval Archt.*, vol. ix, pp. 88–103. 1868.
———.—On the Progress of Liquid Fuel. *Trans. Inst. Naval Archt.*, vol. x, pp. 32–46. 1869.
———.—On Liquid or Concentrated Fuel. *Trans. Inst. Naval Archt.*, vol. xi, pp. 160–174. 1870.
———.—Liquid Fuel for Marine Purposes. *J'l Roy. United Serv. Inst.*, vol. xxix, pp. 689–701. 1885.
STEWART, J. L.—On the Use of Petroleum as Fuel in Steamships and Locomotives, Based on its Employment in that Way on the Caspian Sea and in the Trans-Caspian Region. *J'l Roy. United Serv. Inst.*, vol. xxx, pp. 927–949, pl. xxv. 1886. See also under *Locomotives.*
STROTHER-SMITH, W.—Comparative Performances of Oil-burning Torpedo-boat Destroyers on Trials, with some Observations on Oil-burning. *J'l Am. Soc. Naval Eng.*, vol. xxiii, pp. 412–414. 1911.
ULYANOV, N.—On the Permission of Tugs using Oil Residue Fuel in Fishing Ports. Ribinsk, 1879, 36 pp.
WILSON, H. C.—Liquid Fuel and Methods of Burning It. *Trans. Inst. Marine Eng.*, vol. viii, No. 60, p. 48. 1896.
ZULVER, C.—Oil Fuel for Marine Engines and Boilers. *Mar. Eng. and Nav. Archt.*, March, 1913.

Prevention of Scale in

VOGT.—Erdöl als Mittel gegen den Kesselstein. *Jahresb. Berg-Dampf. Rev. Vereins.* 1894.

Purifying

CARIC, C.—Petroleum zum Kesselreinigen. *Mitth. Praxis Dampfkessel-Dampf-masch-Betriebes*, bd. xxi, p. 317, 1893.

Stationary

ANDOUIN, P.—Application des hydrocarbures liquides (pétrole, goudron, huile lourde) a l'obtention des hautes temperatures et au chauffage des machines à vapeur. *Ann. Chem. Phys.*, ser. 4, t. xv, pp. 30–40, pl. ii, 1868.
BESSON, A. G.—On Petroleum Fuel for Boilers. *Gorn. Jurn.*, 1886, t. iv, pp. 364–372; 1887, t. i, pp. 33–46.
CALDWELL, J.—Electric Power Station, Winding Gear, and Pumping Plant of the Tarbrax Oil Co., Ltd. *Trans. Inst. Min. Engrs.*, vol. xxxi, pp. 221–230; vol. xxxii, p. 102. 1906 and 1907.
COLLINS, B. R. T.—Oil Fuel for Steam Boilers. *J'l Am. Soc. Mech. Eng.*, vol. xxxiii, 1911, pp. 929–965.
KERMODE.—Liquid Fuel Apparatus for Water-tube Boilers. *Engineering*, vol. lxxxix, pp. 510–512. 1910.
LYNE, L. F.—The Use of Crude Petroleum in Steam Boilers. *Trans. Am. Soc. Mech. Eng.*, vol. x, pp. 761–764. 1889.
MENZIN, A. L.—Performance of a 450 h.p. Boiler with Fuel Oil. (Mare Island Navy Yard.) *Eng. News*, May 29, 1913.
PHILLIPS, WM. B.—Fuel Oil used under Stamp Mill Boilers, Shafter, Presidio County, Texas. Hauled in tank wagons 48 miles. *E. and M. J'l*, vol. xc, No. 27, Dec. 31, 1901.
POPOV, N.—Oil Heating in Forges, Boilers, etc., in Moscow. *Gorn. Jurn.*, 1895, t. iii, pp. 1–30, pls. iv. See also under Forges.
VASILEV, A. K.—Petroleum-firing for Boilers. *Gorn. Jurn.*, 1885, t. i, pp. 339–378.
WAGNER, H. A.—Auxiliary Oil-firing in Steam Boiler Plants. *Mech. Eng.*, vol. xxviii, pp. 28–29. 1911.
WEYMOUTH, C. R.—Fuel Economy Tests at a Large Oil Burning Electric Power Plant having Steam Engine Prime Motors. *Trans. Am. Soc. Mech. Eng.*, vol. xxx, pp. 775–796. 1908.
WINKEL, H.—Naphtha als Brennmaterial für Dampfkesselheizung. *Polyt. Journ.*, bd. cccxvi, pp. 782–786. 1901.
WINTER, E.—Kesselfeuerungen für flüssige Brennstoffe. *Allgem. Oesterr. Chem. Techn. Zeit.*, bd. xxvi, pp. 57–61. 1908.

YALOVETSKI, B. Water, Fuel and Steam Boilers, etc. *Jurn. Minist. Put. Soobsch.*, 1879, t. i, pp. 341–352.
ZANGERLE, M.—Ueber die Anwendung des Petroleums zur Dampfkessel-Feuerung. *Kunst. Gewerbe-Bl.*, bd. liii, pp. 721–727. 1867.

Stacks for

DUNN, K. G.—Size of Stacks with Fuel Oil. *J'l Am. Soc. Mech. Eng.*, vol. xxxiii, p. 886. 1911.
WEYMOUTH, C. R.—Dimensions of Boiler Chimneys for Crude Oil at Sea-level, etc. *J'l Am. Soc. Mech. Engrs.*, October, 1912.

BURNERS

Efficiency of

WOODBURY, C. J. H.—On the Relative Efficiency of Kerosene Burners. *J'l Frank. Inst.*, vol. xcvi, pp. 115–117. 1873.

Miscellaneous

BICKFORD, J. S. V.—Petroleum Vapor Burners. *Horseless Age*, vol. ix, pp. 632–635. 1902.
Engineering and Mining J'l.—The Stiltz Fuel-oil Burner. Jan. 25, 1913, p. 232.
FROOM, G. B.—Oil Burners as used on the River Volga. *Trans. Inst. Marine Eng.*, vol. ix, No. 67, p. 50. 1897.
Fuel-Oil J'l.—Hammel Burners. Vol. iii, No. 5, p. 32e, May, 1913.
KALB, C. DE.—A Simple Oil-burning Equipment. *E.* and *M. J'l*, vol. lxxxi, p. 74, 1906.
"LIQUIFUEL" ENGINEERING & CONSTRUCTION CO., Pittsburg, Pa.
MEIDINGER.—Oil-burners, Round and Flat. *Bäd. Gewerbezeit*, 1876.
ORDE, E. L.—Liquid Fuel Burner. *Automot. Journ.*, vol. iv, p. 386, 1900.
PEABODY, E. H.—Mechanical Oil Burners. (Abst. of paper before Soc. Nav. Archt. and Mar. Engrs.) *Eng. News*, May 15, 1913, p. 1000.
SHELBY, C. F.—Oil Burners for Reverberatory Furnaces. *E. and M. J'l*, vol. lxxxix, pp. 31–32. 1910. See also under Furnaces.
SIEMASCHKO, I.—A Type of Burner for Solar Oil. *Zap. Imp. Russk. Tekhn. Obsch.*, g. xxviii, Sept. Trudi. pp. 24–32, pl. 1894.
STILTZ, H. B.—Suggestion for a Fuel-oil Burner. *Power*, vol. xxxii, pp. 166–167. 1910.
TATE-JONES & Co., Pittsburg.—Appliances for Burning Fuel Oil. Pamphlet.
———.—Circular No. 142, August, 1913.
TREUMANN, J.—Burners for highly Carbonized Oils. *Protok. St. Petersb. Polyt. Ver.* 1884.
VASILEV, A. K.—Apparatus for Burning Petroleum. *Zap. Imp. Russk. Teckhn. Obsch.*, Aug.–Sept., pp. 66, 13 pls. 1889.
WATSON, E. P.—Oil Fuel and Oil Burners. *Iron Age*, May 8, 1902.
WEYMOUTH, C. R.—Furnace Arrangements for Fuel Oil. *Trans. Am. Soc. Mech. Eng.*, vol. xxxiii, pp. 879–882. 1911.

COMPOSITION

ALBRECHT, A.—Ueber die Qualität des amerikanischen Petroleum; Kalifornisches und galizsisches Petroleum. *Industr. Blatt.*, bd. xvi, p. 170. 1879.
ALEXIEEV, V.—Russian Petroleum. See under Heating Power.
ALLEN, I. C., and JACOBS, W. A.—Physical and Chemical Properties of the Petroleums of the San Joaquin Valley, California. Bur. Mines, Washington, *Bull.* 19, 1911.
ARNOLD, R.—Physical and Chemical Properties of Southern California Oils. *Bull. U. S. G. S.*, No. 309, pp. 203–205. 1907.
BECKER.—Ueber amerikanisches und russisches Petroleum. *Zeitschr. angew. Chem.*, bd. vii, pp. 216–221. 1894.
BEILSTEIN, F. F., and KURBATOW, A.—Ueber die Natur des Kaukasischen Petroleums. *Ber. deutsch Chem. Ges.*, bd. xiii, pp. 1818–1821; bd. xiv, pp. 1620–1622. 1880 and 1881.
———.—Ueber die Kohlenwasserstoffe des amerikanischen Petroleums. *Ber. deutsch. Chem. Ges.*, bd. xiii, pp. 2028–2029. 1880.

BERTHELOT, M. P. E.—Recherches sur les états du carbone. *Ann. Chim. Phys.*, t. xix, pp. 392–427. 1870.

BIEL, J.—Untersuchungen Amerikanischer und Russicher Petroleumsorten. *Polyt. Journ.*, bd. ccxxxiii, pp. 354–363, 1882. See also *Pharm. Zeitschr. Russl.*, bd. xvii, pp. 129–139; bd. xviii, pp. 162–169, 194–202. 1878, 1879.

BLANCHET, R., and SELL, E.—Die Zusammensetzung einiger organischer Substanzen. *Ann. Chem. Pharm.*, bd. vi, pp. 259–313. 1833.

BLASS, J. C.—Geschichte, Industrie and Chemische Zusammensetzung der amerikanischer Petroleums. *Arch. Pharm.*, bd. cxci, pp. 50–67. 1870.

BLOUNT, B.—The Composition of Commercial Petrols. *Proc. Inst. Antomob. Eng.*, n.s., vol. iii, pp. 301–324. 1909.

BOLLEY, P. A.—Chemisch-tecknische Untersuchungen über das Amerikanische Petroleum. *Schweiz. Polyt, Zeitschr.*, bd. viii, pp. 96–102. 1863.

BOURGOUGNON, A.—Petroleum and its Examination. *J'l Am. Chem. Soc.*, vol. i, pp. 188–204. 1879.

BOUSSINGAULT, J. B.—Sur la composition des substances minérales combustibles. *Ann. Chim. Phys.*, sér. 5, T. xxix, pp. 363–392. 1883.

BUTLEROW, A. I., and ZININA,—. —Problem of the Spontaneous Ignition of Petroleum. *Morsk. Sborn.*, 1871, No. 8, pp. 21–23.

CALMEL, A.—Etude des propriétés physiques des huiles brutes. *Journ. Petrol.*, t. ix, pp. 242–245, 258, 261; t. x, pp. 2–4, 21, 37, 51–53. (1909 and 1910.)

CALVET, —., —DESVIGNEX,—GUILBERT, GUISELIN A. and TASSILY, E.—Unification des Methodes d'Essai des Pétroles. *Compt. Rend. Congr. Internat. Pétrole,* sess. 3, t. ii, pp. 805–807. 1910.

COATES, C. E.—The Series C_nH_{2n-2} in Louisiana Petroleum. *J'l Am. Chem. Soc.*, vol. xviii, pp. 384–388. 1906.

COATES, C. E., and BEST, A.—The Hydrocarbons in Louisiana Petroleum. *J'l Am. Chem. Soc.*, vol. xxv, pp. 1153–1158, 1903, and vol. xxvii, pp. 1317–1321, 1905.

CONSTAM, E. J., and SCHLAPFER, P.—Ueber Treiböle. Serial, *Zeit. des Ver. deutscher Ing.*, Sept. 20, 1913.

COOPER, A. S.—Some Chemical and Physical Characteristics of California Petroleum. *Am. Gas. Light J'l*, vol. lxxiii, pp. 282–285. 1901.

Horseless Age.—The physical Properties of Gasoline and Kerosene (based on Article by L. Berger), April 23, 1913.

MABERY, C. F., and BUCK, D. M.—On the Hydrocarbons in Heavy Texas Petroleums. *J'l Am. Chem. Soc.*, vol. xxii, 1900, pp. 553–556.

MABERY, C. F.—Composition of Texas Petroleum. *J'l Am. Chem. Soc.*, vol. xxiii, 1901, pp. 264–267.

MARCUSSON, J.—Untersuchungen ueber die Zusammensetzung der hochsiedenden Mineralöle. *Chem. Ztg.*, May 1, 1913, p. 533.

——— and VIELITZ, C.—Untersuchungen ueber die Zusammensetzung der hochsiedenden Mineralöle. *Chem. Ztg.*, May 6, 1913, p. 550.

PATTERSON, W. H.—The Chemical Examination of Liquid Fuels. *Chem. Engr.*, Sept., 1913.

PHILLIPS, WM. B.—Texas Petroleum. *Bull. No.* 1, *Univ. Tex. Min. Surv.*, 1901.

——— and WORRELL, S. H.—The Fuels Used in Texas. *Bull.* 307, *Bur. Ec. Geol. and Techn.*, Univ. Tex., Dec., 1913.

WEINWURM, S.—Relation of Flashing and Combustion Temperatures of Mineral Oils. *Mitth. Chem. Inst. Techn. Unters. Wien.*, 1892.

WHITE, CHAS. H.—Results of a Test of Beaumont, Texas, Oil. Rep. Nat. Res. Tex., Merch. Assoc. of N. Y., 1901.

YOUNG, S.—Composition of American Petroleum. *J'l Chem. Soc.*, vol. lxxiii, pp. 905–920. 1898.

CONVERTERS

ROWNTREE, W. B.—Use of Crude Oil in Converters. *E. and M. J'l,* vol. lxxxiv, p. 639. 1907.

ENGINES

A. E. G.

Mechanical Engineer.—The A. E. G. Oil Engine. Aug. 8, 1913..

SARACENI, IGINO.—Mootri a combustione interna. *Industria,* Aug. 10, 1913.

Atlas-Diesel

SARGENT, C. E.—Tests of the Atlas Crude Oil Engine. New Diesel Type Engine. *Iron Age*, vol. lxxxviii, pp. 584–585. 1911.

Automobile Engines

ANDERSON, R. W.—An Examination of the Characteristic Flow of Fuel through a Small Orifice. Soc. Auto. Engrs., June, 1913.
Auto Journal.—Synthetic Petrol. Serial. March 8, 1913.
Automobile.—French Kerosene Motor for Automobile. March 20, 1913.
———.—Motor Spirit to Solve Fuel Problem for the Passenger Car. Feb. 27, 1913.
BAUSCHLICHER, AUGUST.—Brennstoffe für Explosionsmotoren, ihr Vorkommen und ihr thermodynamisches Verhalten. *Motorwagen,* April 30, 1913.
BUCHNER, KARL.—Betrachtungen zur Benzolfrage mit besonderer Berücksichtungen der Spritzvergaser. *Zeit. des Mitt. Motor Ver.*, April 30, 1913.
CLOUGH, ALBERT L.—The Use of Gasoline-Kerosene Mixtures. *Horseless Age,* April 23, 1913.
CRITCHLEY, J. S.—The Fuel Question. Pres't Address Inst. Auto. Engrs. *Horesless Age,* Oct. 22, 1913.
DIETERICH-HELFENBERG, K.—Benzin und Benzol. *Zeit. d. Mitt. Motorwagen Ver.,* Oct. 15, 1912.
EMERSON, HARRINGTON.—Kerosene and the Important Factors in its Combustion. *Horseless Age,* April 2, 1913.
Engineering.—Sources of Motor Fuel. Review of papers read at Imperial Motor Transport Conference. July 25, 1913.
GREBEL, A.—Le probléme de carburant pour les moteurs d'automobiles et les petits moteurs agricoles ou industriels. *Génie Civil,* June 14, 1913.
JAENICHEN, ERNST.—Das Benzol und seine Verwendung für den Betrieb von Kraftfahrzeugen. *Auto Runschau,* June 30, 1913.
MORRIS, H. A.—Will the Automobile be Driven by Kerosene? *Sci. Am.*, Jan. 11, 1913.
ORMANDY, W. R.—The Del Monte Process (smokeless fuel). *Autocar,* April 12, 1913.
———.—Motor Fuels. *Autocar,* March 1 and 22, 1913.
POPE, N. B.—Low Grade Fuel for Motor Trucks. *S. A. E. Bull.*, Jan., 1913.
———.—Gasoline and its Future. *S. A. E. Bull.*, Feb., 1913.
———.—Low Grade Fuel for Motor Trucks. *Automobile,* Jan. 23, 1913.
POTTER, A. E.—Liquid Motor Fuels. *S. A. E. Bull.*, April, 1913.
REDWOOD, SIR BOVERTON, and LEWES VIVIAN B.—Fuel for Motor Vehicles. Abst. of paper on "Petrol Substitutes." Imperial Motor Transport Conference. *Col. Guard.*, July 25, 1913.
Scientific American.—Gasoline and its Substitutes. March 22, 1913.
SECOR, JOHN A.—Kerosene Engines. *S. A. E. Bull.*, March, 1913.
———.—The Waning Supply of Gasoline. *Sci. Am. Sup.*, April 26, 1913.
SLAUSON, HAROLD WHITING.—Solving the Fuel Problem for the Motor Truck. *Mach.*, N. Y., Oct., 1913.
TIPPER, HARRY.—Motor Fuels. *S. A. E. Bull.*, April, 1913.
WALFORD, ERIC W.—Notes on Paraffin. *Autocar,* April 19, 1913.

Bolinder

Engineering.—Bolinder's Crude-oil Engine. April 18, 1913.

de La Vergne

TOWL, F. M.—Test of an 85-h. p. de La Vergne Oil Engine. *J'l Am. Soc. Mech. Engrs.,* Nov., 1911.

Diesel

ALLNER, W.—Use of Tar in Diesel Engines. *Journ. Gas Light,* vol. cxv, p. 106, 1911.
BOOTH, W. H.—What Oil will do in the Internal Combustion Engine of Diesel Type. *Petrol. Rev.*, vol. xxv, pp. 97, 145–146. 1911.
BRIGHT, D. M.—The Application of Diesel Engines to Land and Marine Work. *Can. Engr.,* Nov. 7, 1912.

Burow and Dobbelstein.—Untersuchung eines mit Teeröl betriebenen 480 P. S Dieselmotors. *Glückauf*, June 22, 1912.

Carels, Gaston L.—The Development of the Diesel Internal Combustion Engine. *Cassier's Mag.*, London, March, 1913.

Clark, H. A.—The Diesel Engine. *Proc. Inst. Mech. Engrs.*, 1903, pt. 3, pp. 395–455.

Diesel, Rudolph.—The Diesel Oil Engine and its Industrial Importance, Particularly for Great Britain. *Inst. Mech. Engrs.*, March 15, 1912.

———.—The Present Status of the Diesel Engine in Europe, and a few Reminiscences of the Pioneer Work in America. *J'l Am. Soc. Mech. Engrs.*, June, 1912.

Dornig, Mario.—L'importanza attuale e l'avvenire dei motori Diesel. *Monit. Tec.*, June 20, 1912.

Electrical Review, London.—Notes on the Maintenance of the Diesel Engine. April 19, 1912.

———.—Water Supply for Internal Combustion Engines (500 h. p. Diesel). Aug. 1, 1913.

Elektrotechnische und Polytechnische Rundshau. Weltausstellung Gent. Serial. Aug. 21, 1913.

Engineer, London.—Horizontal Diesel Engines at the Kingston Electricity Works. Oct. 3, 1913.

———.—New Generator for Diesel Engines. Sept. 19, 1913.

———.—An Interesting Small-powered Diesel Motor. March 14, 1913.

———.—The Diesel Engine in America. Aug. 22, 1913.

———.—The John Samuel White Diesel Engine. June 6, 1913.

Engineer, London.—Some Stationary British Diesel Engines. May 9, 1913.

———.—The F. I. A. T. Diesel Motor. May 31, 1912.

Engineering.—Diesel Engine Cylinder Dimensions. Sept. 26, 1913.

———.—Diesel Engines at the Turin Exposition (engines built by Sulzer Bros.). March 8, 1912.

———.—Four Cylinder Four-cycle Diesel Engines. May 24, 1912.

Fuel Oil Journal.—History of the Development of the Diesel Oil Engine. Vol. iv, No. 5, pp. 54–55. Nov., 1913.

Gruszkiewicz, J.—Das Rohöl in seiner Verwendung für Dieselmotoren. *Naphta*, bd. xvi, pp. 131–132. 1908.

Haas, Herbert.—Principles of the Diesel Oil Engine. *E.* and *M. J'l*, April 26, 1913, p. 843.

Hake, W. B.—Die Entwickelung und Bedeutung des Rohölmotorsystem (Diesel). *Petrol. Zeitschr.*, bd. vi, pp. 945–946. 1911.

Heath, Geo. E.—The Development of Diesel Engines for Stationary Purposes. *Cassier's*, Lond., March, 1913.

Holliday, P. A.—A New Diesel Engine Formula. *Engr.*, London, April 5, 1912.

Howell, S. M.—The Diesel Engine. *Mach.*, N. Y., April, 1912.

Kimball, G. H.—An Operator's View of the Diesel Engine. *Power*, vol. xxxiii, p. 119. 1911.

Kribs, Gordon.—The Cost of Generating Power with Diesel Oil Engines (Sherman and Cleburne, Texas). *Can. Engr.*, July 10, 1913.

Kutzbach, K.—Die flüssige Brennstoffe und ihre ausnutzung in der Verbrennungs-Kraftmachine, mit besonderer Berücksichtigung des Dieselmotors. *Zeitschr. Ver. deutsch. Ing.*, bd. li, pp. 521–527, 581–586. 1907.

Lane, F.—Solution of the Question of Fuel for Diesel Engines. *Fuel Oil J'l*, vol. ii, No. 4, pp. 14–15, Oct., 1912.

———.—Heavy Petroleum Residues Satisfactory for the Diesel Engine. *Fuel Oil J'l*, vol. ii, No. 5, pp. 49–50, Nov., 1912.

Nettmann, P. H. R.—Large Diesel Engines. *Cassier's*, Lond., March, 1913.

Oebbeke, K.—Ueberblick über den heutigen stand des Dieselmotorbaues und die Versorgung mit flüssigen Brennstoffen. *Zeitschr. Ver. deutsch. Ing.*, bd. lv, pp. 1345–1353. 1911.

Pfleiderer, R. A.—New Diesel-driven Pumping Installation at Rugby Water Works. *Mech. Engr.*, Lond., Dec. 20, 1912.

Rath, Herr.—Teer und Teeröl als Treibmittel für den Dieselmotor. *Glückauf*, June 22, 1912.

Royds, R., and J. W. Campbell.—The Oil Consumption and Mean Effective Pressure of Diesel Engines. *Engr.*, Lond., April 11, 1913.

Russel, Paul H.—Diesel Engine Design. *Mech. Wld.*, June 28, 1912.

Rye, A. N.—Gas and Oil Engines for Electric Supply Stations. *Elec. Rev.*, Lond., May 2, 1913.

Sankey, H. Riall.—Heavy Oil Engines. (Diesel). *Jour. Soc. of Arts*, Oct. 4, 1912.

SAUVAGE, E.—Le Moteur Diesel. *Rev. Gén. des Sciences*, Oct. 30, 1912.
SCHUBELER, F.—Modern Diesel Oil Engines. *Electrician*, vol. lxviii, pp. 662–663. 1911.
SOWTER, WM. J. A.—The Diesel Engine from the User's Standpoint. (Abst. paper before Dublin Sec. I. E. E.) *Mech. Wld.*, July 26, 1912. See also *Electrician*, Lond., May 31, 1912.
VAN LANGENDONCK, C.—Power Applications of Diesel Engines in Industrial Plants. *Eng. Mag.*, Sept., 1913.
WANSBROUGH, W. D.—British Oil Engine Practice. *Cassier's Mag.*, Lond., March, 1913.
WITZ, AIME.—Les Vingt Aus du Moteur Diesel. *Tech. Mod.*, Aug. 1, 1913.
Zeit. des Ver. deutscher Ing.—Grossdieselmotoren, ihre Brennstoffe, Konstruktion und Anwendungsgebiete. July 19, 1913.

Semi-Diesel

Engineer, London.—Two-cycle "Semi-Diesel" Engine. (Petters three cylinder.) Aug. 15, 1913.

Falk, Kerosene

WILE, H. D.—Test of a Kerosene Oil Engine. *Elec. Wld.*, Aug. 23, 1913.

Junkers

BAKER, JOSEPH B.—The Junkers Oil Engine. (A valveless engine, with two pistons per cylinder for utilizing cheapest grades of fuel.) *Iron Age*, Aug. 1, 1912.
ERIC, H.—Le moteur "Junkers" à combustion interne. *Rev. Indus.*, Dec. 9, 1912.
JUNGE, F. E.—The Junkers Oil Engine. *Power*, Jan. 23, 1912.
Scientific American Supplement.—The Junkers Engine. March 2, 1912.

Langen and Wolf

The Engineer, London.—The Langen and Wolf Diesel Engine. July 26, 1912.

Leyland

Tram and Railway World.—Petrol Tramway Cars at Morecambe. Feb. 8, 1912.

McKechnie

Mechanical Engineer.—Internal Combustion Engine for Heavy Fuel Oils (James McKechnie engine). Jan. 12, 1912.

Nurnberg Two-Cycle

LOUIS SHANE.—*J'l Am. Soc. Nav. Engrs.*, Aug., 1913.

Primm

Fuel Oil Journal.—Vol. iii, No. 5, p. 32, May, 1913.

Rocket

ARMSTRONG, T. H.—The Rocket Oil Engine. *Trans. Inst. Min. Eng.*, vol. xlix, pp. 74–93, pl. xix, 1896.

Sulzer-Diesel

COCHAND, J., and HOTTINGER, M.—Versuche an einer Sulzerschen 300 pferdigen Diesel-motorenanlage mit Abwärmeverwerthung. *Zeitschr. des Ver. deutsch. Ing.*, March 23, 1912.

Economy of

MERIAM, J. B.—The Relative Economy of Gas Engines and Other Sources of Power. *J'l Cleveland Engng. Soc.*, Dec., 1911.

Efficiency of

CALLENDAR, H. L.—The Effect of Size on the Thermal Efficiency of Motors. *Proc. Inst. Automob. Eng.*, n. s., vol. i, pp. 223–292, 1907.

CLERK, D.—The Limits of Thermal Efficiency of Internal Combustion Engines. *Proc. Inst. Civ. Eng.*, vol. clxix, pp. 121–182. 1907.

MARKS, L. S.—Horse-power, Friction, Losses and Efficiency of Gas and Oil Engines. *Trans. Am. Soc. Mech. Eng.*, vol. xxx, pp. 423–435. 1908.

MOULTON, S. A.—A Comparison of Efficiencies and Costs of Steam, Water, Gas and Oil Power Generation. Extract from Rep. of Maine State Water Storage Commission. *Engineering and Constr.*, Sept. 4, 1912.

TOWL, F. M.—Test of an 85-h. p. Engine. *Trans. Am. Soc. Mech. Eng.*, vol. xxxiii, pp. 1351–1360. 1911.

TOWLE, H. L.—The Ultimate Limit of Speed of Internal Combustion Engines. *Am. Machinist*, vol. xxviii, pp. 317–319. 1905.

WENTWORTH, J. F.—The Efficiency of the Marine Oil Engine. *Mar. Engng.*, vol. ix, pp. 594–596. 1904.

Marine

ADAMS, L. S.—Motor Boats for Naval Service. *Trans. Soc. Nav. Archt. Eng.*, vol. xv, pp. 69–96. 1907.

ALLEN, PERCY R.—The Possibilities of the Internal Combustion Engine Applied to Marine Propulsion. *Cassier's Mag.*, Dec., 1911.

ALLEN, R. P.—The Internal Combustion Engine for Marine Propulsion. *Cassier's Mag.*, vol. xl, pp. 705–736, 1911.

BOCHET, A.—Application des Moteurs à Pétrole à la Navigation. *Mem. Soc. Ing. Civ.*, 1903, vol. i, pp. 877–888, pl. 54.

CERIO, EDWIN.—Motori termico a doppio Stantuffo. *Rev. Marittima*, July-Aug., 1912.

CONE, H. I.—Use of Fuels in the United States Navy, *J'l Am. Soc. Nav. Engrs.*, Nov., 1912.

CROWLY, R. W.—Marine Oil Engine Power. Present Accomplishments. *Gas and Oil Power*, vol. vi, pp. 247–250, 1911.

DURAND, W. F.—Progress in Marine Engineering During the Past Fifteen Years. *Marine Engineering*, March, 1912.

Engineer, London.—A Thirty-day Non-stop Run of a Marine Oil Engine. Jan. 26, 1912.

———.—An Analysis of the Claims of the Marine Internal Combustion Engine. Also editorial, March 15, 1912.

———.—The Motorship "Juno." Serial, Nov. 15, 1912.

Engineering.—The Canadian Pacific Railway's Oil-fuel Burning T-S. S. "Princess Alice." Dec. 8, 1911.

———.—The Ocean-going Oil-engined Ship "Sembilan." March 15, 1912.

———.—The Cargo Ship "France." Oct. 10, 1913.

Engineering News.—The New Hamburg-American Oil Engine Ship "Christian X." Oct. 3, 1912. See also *Fuel Oil J'l*, vol. iii, No. 3, p. 54, March, 1913; and vol. ii, No. 4, pp. 10–12, Oct., 1912.

HALL-BROWN, E.—Presidental Address. *Trans. Inst. of Engrs. and Shipbuilders in Scotland.* Oct. 24, 1911.

HARMSEN, CONRAD.—Winke für den Verkauf von Schiffsölmaschinen. *Motorwagen*, July 20, 1912.

LAAS, W.—Large Motor Vessels. *J'l Am. Soc. Nav. Engrs.*, Nov., 1911.

LAKIN-SMITH, C.—Oil Engines for Marine and Land Purposes. *Mech. Engr.*, Sept. 12, 1912.

———.—Land and Marine Oil Engines. *Prac. Engr.*, Nov. 7, 1912.

LUCAS, THEODORE.—The Possibilities of the Marine Oil Engine. *Int. Mar. Engng.*, Feb., 1913.

MCALLISTER, C. A.—Economy in the Use of Oil as Fuel for Harbor Vessels. (Tug "Golden Gate.") Pl. *Soc. Nav. Archt. and Marine Eng.*, Nov., 1911.

Marine Review.—Crude Oil Engines. Type adopted by the Italian Navy. Aug., 1912.

———.—Dahl Oil-burning System. (Pacific Coast Vessels.) Aug., 1912.

MARIOTTI, ENRICO.—Motore ad olio pesante, di grande potenza, tipo marino veloce. *Ingeg. Ferro.*, July 15, and Oct. 15, 1912.

MENDEL, J.—Das Heizöl und die Kriegsmarinen. *Petrol. Zeitschr.*, bd. vi, pp. 2293–2301. 1911.

MENTZ, WALTER.—Schiffoelmaschinen. Serial. *Schiffbau*, April 9, 1913.

PARSONS, SIR CHARLES ALGERNON.—Presidential Address. *Trans. N. E. Coast Inst. of Engrs. and Shipbldrs.*, Nov., 1912.

PEABODY, E. H.—Developments in Oil Burning. *Soc. Nav. Archts. and Mar. Engrs.*, Nov. 21, 1912.
ROBINS, W. B.—Description and Trial of the U. S. Torpedo Boat Destroyers Warrington and Mayrant. *Journ. Am. Soc. Nav. Engrs.*, Nov., 1911.
RONCO, N.—Sulla sostituzione del combustibilo liquido al carbone. *Ann. della Soc. d. Ing. e. d. Arch. Ital.*, May 16, 1912.
Scientific American Supplement.—A High-power Oil Engine for Tug-boat Service. (300 h. p., 4-cylinder oil engine for the experimental tug-boat "Schlepp.") May 11, 1912.
SOMMER, ALBERT.—Petroleum as a Source of Power for Ships. *J'l Am. Soc. Nav. Engrs.*, Nov., 1912.
THORNYCROFT, J. I.—Internal Combustion Engines for Marine Purposes. *Cassier's Mag.*, vol. xxxv, pp. 225–240. 1908.
TIMPSON, F. M.—Oil Engines for Marine Purposes. *Trans. Inst. Marine Eng.*, vol. xviii, No. 134, pp. 42, pl. 1907.
WENTWORTH, J. F.—The Efficiency of the Marine Oil Engine. *Marine Engineering*, vol. ix, pp. 594–596. 1904.
WILDT, O. H.—Moteur à huile lourde "Kromhout" à Chambre de Combustion incandescente. *Gén. Civ.*, Feb. 1, 1913.
YOUNGER, A. S.—Development in Marine Engines since 1880. *Mech. Engr.*, Sept. 12, 1913.

Brons, Marine

Engineering.—Internal-Combustion Engines for German Fishing Boats (the Brons engine). March 1, 1912.

Diesel, Marine

ATKINS, A. K.—Diesel Engines for Naval Purposes. *Proc. U. S. Naval Inst.*, June, 1912.
BRAKEL, F. MULLER VAN.—Performance of Notable Sea-going Diesel-engined Vessels (cargo boat *Vulcanus*). *Int. Mar. Eng.*, Sept., 1912. (Comp. Wildt, O. H.)
Canadian Engineer.—A New Canadian Oil-engined Ship, the "Fordonian." Jan. 23, 1913.
CEA, M. B.—The First Trans-Atlantic Diesel Liner "Sedandia." *Cassier's Mag.*, Oct., 1912.
COLELL, RICHARD.—Die Wirtschaftlichkeit der Dieselmotorschiffe. *Schiffbau*, April 24, 1912.
DAVISON, G. C.—Heavy Oil Engines for Marine Propulsion. (Otto and Diesel cycles.) *Soc. of Nav. Archts. and Marine Engrs.*, Nov., 1911.
DIESEL, RUDOLPH.—Les Applications du moteur Diesel à la locomotion et à la navigation. *Tech. Moderne*, June 1, 1912.
DROSNE, M.—La Propulsion des Navires de Combat. (Diesel moteur.) 1st part. *Tech. Mod.*, Dec., 1911.
DUMANCIS, P.—Application des moteurs Diesel aux Navires de guerre. *Tech. Mod.*, April 15, 1913.
Engineer, London.—A French Diesel Engine. May 2, 1913.
———.—The Motor Ship "Christian X." July 18, 1913.
———.—The Motor Ship "Eavestone." Oct. 25, 1912.
———.—The Starting of Diesel Marine Engines. Jan. 10, 1912.
———.—Some Impressions of Continental Marine Diesel Engine Practice. Dec. 8, 1911.
———.—A New Marine Diesel Engine. (500-h. p., two-cycle.) April 19, 1912.
———.—German Motor Notes. (Diesel Marine Motors.) Oct., 1912.
———.—The "Monte Penedo's" Engines. (Sulzer two-cycle Diesel.) Sept. 6, 1912.
Engineering.—100-shaft-horsepower Reversible Diesel Marine Engine. Feb. 16, 1912.
———.—Oil-tank Steamer Driven by Diesel Engines. April 19, 1912.
———.—The German Motor-driven Ship "Monte Penedo" (South American Service. Two 4-Cylinder Reversible Two-cycle Diesel-Sulzer engines.) Sept. 6, 1912.
———.—The Twin-screw Motor Ship "Selandia." *Engr.*, London, March 8, 1912. See also Fuel Oil J'l, vol. ii, No. 3, p. 52, Sept., 1912.
———.—The Oil-engined Ship "Fordonian." Dec. 13, 1912.
———.—The Italian Tugboat "Savoia." Dec. 6, 1912.

Engineering.—Results of First Voyage of the Oil-engined Ship "Christian X." Jan. 3, 1913.
FLANNERY, J. FORTESCUE.—Diesel Engines. *Marine Rev.*, Feb., 1912.
Fuel Oil Journal.—Motor Yacht "Idealia." First in U. S. equipped for heavy oil. Vol. ii, No. 3, p. 52, Sept., 1912.
GOURIET, M.—Le "Selandia" et le "Jutlandia." *Gênie Civil*, Nov. 30, 1912.
HODGINS, G. S.—Diesel Engines for Ocean Ships. *Marine Rev.*, April, 1912.
Int. Marine Engineering.—First Long Voyage of Motor-ship "Eavestone." Feb., 1913.
KAEMMERER, W.—Die Vendung vom Dieselmachinen zum Antrieb von grösseren See-schiffen. Ills. Serial, 1st part. *Zeitschr. des Ver. deutsch. Ing.*, Jan. 20, 1912.
KNUDSEN, G.—Results of Trials of the Diesel-engined Sea-going Vessel "Selandia." *Inst. Nav. Archt. and Engng.*, April 5, 1912.
KNUDSEN, I.—Performance on Service of the Motor-ship "Suecia." *Mech. Engr.*, June 27, 1913.
Marine Engineering.—The First American Built Diesel Engined Oil Barge. (300 h.p. engine for a 200-ft. steel motor barge.) March, 1912.
———.—The Koreiwo Clutch for the Diesel Marine Engine Installations. Feb., 1912.
Marine Review.—Motor-driven Ship "Fordonian." July, 1913.
MILTON, J. T.—The Diesel Engine for Marine Power. *Gas and Oil Power*, vol. vi, pp. 159–162, 183–187. 1911.
———.—Diesel Engines for Sea-going Vessels. *Trans. Inst. Naval Archt.*, vol. liii, pp. 53–102, pl. i. 1911.
OLSON, OLE K.—The Diesel Engine as Motive Power in the Merchant Marine, with Special Reference to the First Successful Motor-ship, "Christian X." *Journ. Assn. of Engng.*, 1912.
ORDE, E. L.—The Diesel Oil Engine Geared Turbine, and Suction Gas Engine. Disc. before N. E. Coast Inst. of Engrs. and Shipbuilders. Also editorial. *Mech. Engr.*, April 12, 1912.
Power.—First American-built Marine Diesel Engines. June 3, 1913.
Schiffbau.—Doppelschrauben-Motorfrachtschiff, "Monte Penedo," der Hamburg-Südamerikanischen Dampf-schiffs Gesellschaft. Sept. 25, 1912.
SHANNON, D. M.—Some Aspects of Diesel Engine Design. *Mech. Engr.*, May 3, 1912. Read before Inst. of Engrs. and Shipbuilders in Scotland. 1st part.
SILLINCE, W. P.—The Possibilities and Limitations of the Marine Diesel Engine. *Cassier's Mag.*, Lond., March, 1913.
SUPINO, G.—Sull' inversione di marcia dei motori Diesel marini. *Industria*, Nov. 3, 1912. Serial.
———.—Sulle stato attuale dell' applicazione dei motori Diesel alla marina. *Rivista Marrittima*, Nov., 1912.
Technique Moderne, Le.—Les nouveaux moteurs Diesel marins et en particular les essais du petrolier "Juno." April 1, 1913.
VERLOOP, J. H. H.—De Toepassing van Dieselmotoren aan boord van zeeschepfen. *De·Ingenieur*, Oct. 7, 1911.
WILDT, O. H.—L'Emploi du Moteur Diesel à la propulsion des Navires de haute mer. (1900 ton tank-ship "Vulcanus.") *Gén. Civ.*, July 20, 1912.
WILSON, J. RENDELL.—Large Russian Vessels Propelled by Diesel Engines. *Inst. Mar. Engng.*, Jan., 1912.
———.—Russian High-speed Marine Diesel Engines. (Vertical type, 180-h.p., weighs 33 lbs. per h.p.) *Int. Mar. Engng.*, July, 1912.
———.—The Semi-Diesel Heavy Oil Engine. *Marine Rev.*, Oct., 1912.
———.—Diesel Engines in Whalers. *Mar. Rev.*, May, 1912.
———.—Success of the First Large Diesel-motor-driven Motor. *Int. Mar. Engng.* April, 1912.
Zeitschrift des Ver. deutsch. Ing.—Die Maschinen des Diesel-schiffes "Monte Penedo." Sept. 21, 1912.

Carels-Diesel, Marine

Engineering.—The Carels-Diesel Marine Engine. Jan. 19, 1912.
Marine Engineering.—Motorship "Eavestone" fitted with Carels-Diesel Engines. Oct., 1912.

Carels-Tecklenberg-Diesel, Marine

Engineer, London.—Motor-ship "Rolandseck." Nov. 22, 1912; Dec. 13, 1912, and Aug. 22, 1913.

KAEMMERER, W.—Das Dieselschiff "Rolandseck." *Zeit. d. Ver. deutscher Ing.*, Jan. 4, 1913.

WILSON, J. RENDELL.—Single Screw Motor-ship of 1500 h.p., the "Rolandseck" *Mar. Engng.*, March, 1913.

Semi-Diesel, Marine

Engineer, London.—20-h.p. Marine Oil Engine. June 20, 1913.

Engineering.—Semi-Diesel Engine on the Yacht "Mairi." Feb. 23, 1912.

Marine Review.—Motor-ship "Isleford." Aug., 1913.

Djinn, Marine

Engineer, London.—23-h.p. Djinn Petroleum Marine Engine. March 7, 1913.

Junkers, Marine

Engineering.—The Junkers Marine Oil Engine. Nov. 24, 1911.

Marine Engineering.—The Application of the Junkers Oil Engine to Marine Work. July, 1912.

Mariotti, Marine

MARIOTTI, ENRICO.—Heavy-oil Marine Engines. *Industria*, Jan. 5, 1912.

"Monobloc," Marine

Engineering.—10-h.p. "Monobloc" Marine Oil Engine. Aug. 16, 1912.

Nuremberg, Marine

Engineering.—The Nuremberg Marine Oil Engine. Feb. 9, 1912.

Otto, Marine

DAVISON, G. C.—Heavy Oil Engines for Marine Purposes. (Otto and Diesel cycles.) *Soc. Nav. Archts. and Mar. Engrs.*, Nov., 1911.

Sulzer-Diesel, Marine

DANTIN, CH.—Les Moteurs Sulzer-Diesel a Deux Temps du Cargo "Monte Penedo." *Génie Civil*, Oct. 26, 1912.

Engineer, London.—The Motorship "Monte Penedo." (Sulzer two-cycle Diesel engines.) Aug. 30, 1912.

———.—The Motor-ship "Monte Penedo." Sept. 12, 1913.

WILSON, J. RENDELL.—Sulzer-Diesel-engined Ship for New York-Rio Service. (Twin-screw, 6500 tons, "Monte Penedo.") *Engng.*, Oct., 1912.

Zeit. d. Oest. Ing. u. Arch, Ver.—Die Sulzer-Maschinen des Dieselschiffes "Monte Penedo." Oct. 4, 1912.

Sulzer, Marine

Mechanical Engineer.—Two-stroke Cycle Continuous Combustion Oil Engines for Ships. Feb. 21, 1913.

Werkspoor Motor, Marine

Engineer, London.—The Emanuel Nobel. March 28, 1913.

Williamson, Marine

Engineer, London.—An Oscillating Marine Motor. Feb. 21, 1913.

Miscellaneous

ABLAND, W. E.—A Petroleum Motor. *J'l Frank. Inst.*, vol. lxxxviii, p. 87. 1874.

ALLEN, IRVING C.—Heavy Oil as Fuel for Internal Combustion Engines. *Techn. Paper* 37, *Bur. Mines*, Washington, 1912. *J'l Elec., Pet. and Gas*, July 26, 1913.

ARNOLD, B. H.—Fuels and Lubricants for Internal Combustion Engines. *Gen. Elec. Rev.*, Oct., 1913.

AUSTIN, E.—The Internal Combustion Engine and Petroleum: A Criticism and a Suggestion. *Petrol. Rev.*, vol. vii, pp. 445, 473. 1902.

Autocar.—A Paraffin Gas Producer. April 20, 1912.

BANO, LASZLO.—Oil Engines in a Hungarian Municipal Power Plant. *Power*, April 16, 1912.
BEAUMONT, W. W.—Oil Engines for Agricultural Purposes. *Journ. B'd. Agric.*, vol. x, pp. 435–460. 1904.
BERNDT, O.—Die Erdölmotoren auf der internationalen Ausstellung für Bäckerei, Konditorei und verwandte Gewerbe zu Mainz im August, 1893. *Zeitschr. Ver. deutsch. Ing.*, bd. xxxviii, pp. 195–198, 215–219. 1894.
BICKERTON, H. N.—Gas, Oil and Petrol Engines. *Gas and Oil Eng. Rec.*, vol. ii, pp. 250–251, 274–275. 1906.
BREWER, R. W. A.—Liquid Fuel for Internal Combustion Engines. *Gas and Oil Eng. Rec.*, vol. v, 1907.
BÜCHI, ALFRED.—Modern Continental Oil-engine Practice. *Cassier's*, Lond., March, 1913.
BURSTALL, F. W.—Some Future Developments of Heat Engines. *J'l West. Scot. Ir. and Steel Inst.*, vol. xiii, pp. 98–110, 139–146, 151–156. 1906.
BUTLER, E.—Practical Management of Gas and Oil Engines. *Gas and Oil Power*, vol. iv, pp. 203–204, 234–235. 1909.
CANTON, M.—Das mechanische Aequivalent der Verbrennung und Konstrucktion eines rationellen Verbrennungsmotor. *Physik. Zeitschr.*, bd. vi, pp. 805–806. 1905.
CAPITAINE, E.—Petroleum Kraftmaschine. *Zeitschr. Ver. deutsch. Ing.*, bd. xlii, pp. 1458–1462, pl. xix. 1899.
CHATTERTON, A.—Experiments in pumping with Oil Engines at Melrosapuram (India). *Bull. Dept. Agric. Madras*, vol. iii, pp. 35–51. 1905.
CLERK, D.—The Testing of Petrol Engines. *Proc. Inst. Autom. Engrs.*, vol. vii, pp. 22. 1905.
———.—Internal Combustion Engines. *Cantor Lectures*, vol. viii. 1905.
———.—The Present Position of Gas and Petrol Engines. *Electrician*, vol. lix, pp. 774–677. 1907.
CROWLEY, R. W.—Solid Gasoline as a Fuel for Gas Motors. *Com. Veh.*, Nov., 1911.
DUNCANSON, FRANK.—Notes on Two-cycle Oil Engines. *Mech. Engr.*, Mar. 1, 1912.
ELLIS, L. W., and DRAY, W. R.—Power from Kerosene. *Sci. Am. Sup.*, Feb. 15, 1913.
Engineer, London.—A New Crude Oil Engine. Dec. 1, 1911.
Engineering.—Petrol and Alcohol Internal Combustion Engines. *Rev. of Bull.* 43, *U. S. Bur. Mines*, May 23, 1913.
———.—Internal Combustion Engines at the Ghent Exposition (Navy tank steamer). August 1, 1913.
———.—Water-cooled Clutch and Slipping Gear for Oil-Engine Drives. Oct. 17, 1913.
FERNALD, R. H.—The Status of the Gas Producer and of the Internal Combustion Engine. *Techn. Paper* 9, *Bur. Mines*, Washington, 1912.
H.-R.—Der Zweitakt-Rohölmotor. *Seifenfabrik*, bd. xxxi, pp. 649–650. 1911.
HIRSHFELD, C. F.—The Principles of Fuel-Oil Engines. *Wis. Engr.*, May, 1913. *Sci. Am. Sup.*, July 19, 1913. Serial.
JACKSON, EARLE D.—Oil Engines for Central Station Prime Movers. *Elec. Wld.*, May 4, 1912.
JUNGE, F. E.—German Progress in Large Oil Engines. *Power*, Oct. 22, 1912.
KIMBALL, G. H.—What is the Future of the Oil Engine in the United States? *Eng. News*, May 20, 1912.
KNOWLES, C. R.—The Oil Engine in Railway Water Service. *Ry. Age Gaz.*, Aug. 15, 1913.
LETOMBE, LEON.—Moteurs à combustion Interne et Gazogènes. *Tech. Mod.* (Supplement), Dec. 15, 1912.
LOEBELL, H.—Die flüssige Brennstoffe und ihre Verwendbarkeit im Grosskraftmaschinen. *Pet. Zeitschr.*, bd. vi, pp. 946–952. 1911.
LUMET, G.—La question du Carburant à bon marché. *Tech. Mod.*, May 15, 1913.
MARIOTTI, E.—Nuovo motore ad olio pesante applicato ad una automotrice ferroviaria. *Ing. Ferro.*, Dec. 16, 1911.
MATHOT, R. E.—Comparison of Gas, Oil and Steam Motive Powers. *Power*, March 5, 1912.
OSTERGREN, O. P.—Classification of Oil Engines. *Power*, Feb. 11, 1913.
POTTER, A. A., and CARLSON, W. W.—Brake Test on a 75-h.p. Oil Engine. *Elec. Wld.*, Jan. 11, 1913.
Power.—The Oil-Motor Industry in Italy. Abst. trans. from *Des Oelmotor*, Oct. 7 1913.

PRICE, W. T.—The Significance of Oil-engine Developments. (Phila. F'dry Assoc.) *Iron Trd. Rev.*, Dec. 26, 1912.

RAND, J. P.—Test of a Kerosene Burning Oil Engine. *Sib. J'l Eng.*, Feb., 1912.

ROLLASON, A., and TAYLOR, A. W.—The Production of Motor Spirit from Coal. *Col. Guard.*, Sept. 19, 1913.

SCHAARSCHMIDT, OSCAR.—Die Treibmittel des Verbrennungs-motors. *Schiffbau*, Feb. 26, 1913.

SECOR, JOHN A.—The Gasoline and Kerosene Situation. Address before Indiana Section Soc. Autom. Engrs. *Sci. Am.*, May 19, 1913.

SETZ, H. R.—Oil Engines. *Trans. Am. Soc. Mech. Eng.*, vol. xxxiii, pp. 1167–1200. 1911.

SIMPICH, F.—Oil Engines for Mesopotamia. *U. S. Cons. Rep. No.* 357, pp. 145–147. 1910.

SKINNER, R. P.—Petroleum-burning Motors for Agricultural Purposes (Russia). *U. S. Cons. Rep. No.* 356, p. 54. 1910.

STEPHENSON, G. B.—Petroleum Engines. *U. S. Cons. Rep. No.* 357, p. 145. 1910.

STREETER, R. L.—The Internal Combustion Engine in Modern Practice. *Eng. Mag.* vol. lxii, pp. 57–74, 185–205, 349–370. 1911.

STRONG, R. M., and STONE, LAUSON—Comparative Fuel Values of Gasoline and Denatured Alcohol in Internal Combustion Engines. *U. S. Bur. Mines, Bull.*, 43; and *Bull.* 32. 1912.

SUPLEE, H. H.—Historical Review of the Development of the Internal Combustion Engine. *Cassier's Mag.*, vol. xxxiii, pp. 3–22. 1907.

TOOKEY, W. A.—Oil Engines. *Trans. Manchester Assoc. Eng.*, 1908, pp. 21–78.

ULBRICHT, T. C., and TORRANCE, C. E.—American Practice in the Rating of Internal Combustion Engines. *Sib. J'l Eng.*, April 12, 1912, and *Power*, July 23, 1912.

U. S. Special Consular Report.—Gas and Oil Engines in Foreign Countries, vol., xxiii, pt. i, pp. 188, iv. 1901.

VENTON-DUCLAUX, L.—Les Moteurs à Naphtaline. *Tech. Mod.*, Nov. 1, 1912, and *Mem. Soc. Ing. Civ. de France*, Oct., 1912.

WEINREB, F.—Ueber Rohölmotoren. *Electrotech. u. Maschinenbau*, May 25, 1913, p. 444.

Observations on

WENTWORTH, JOHN F.—Observations on the Oil Engine. *Power*, March 11, 1913, p. 338.

Principles of

Hirschfield.—The Principles of Fuel-oil Engines. *Wisconsin Eng.*, May, 1913, p. 331.

Rolling Mill

BAUDISCH, H.—Eine Diesel anlage für Walzwerksbetrieb. *Zeit. Oest. Ing. u. Arch. Ver.*, July 12, 1912.

Schimanek

SCHIMANEK, EMIL.—Die Steigerung der Leistung von Verbrennungsmotoren und ein neuer Sechstaktmotor. *Zeit. des Ver. deutscher Ing.*, Jan. 25, 1913.

Snow

BALLIN, A. E.—New Heavy-oil Engine. *Power*, August 12, 1913.

Stamp Mill

SEAGER, J. A.—Oil Engines for Driving Gravity Stamps. *E. and M. J'l*, vol. xcii, pp. 851–852. 1911.

Wentworth

WENTWORTH, JOHN F.—Observations on the Oil Engine. *Power*, Mar. 11, 1913.

FIRES

WILLEY, DAY ALLEN.—Oil Fires in the Southwest. *Sci. Amer.*, Jan. 10, 1903.

To Extinguish

WICKERSHAM, S. M.—To Extinguish Oil Fires. . *Proc. Eng. Soc. West. Penn.*, vol. ix, pp. 279–281. 1893.

FORGES

EVANS, H. A.—Oil as Fuel in Forges. *Iron Tr. Rev.*, vol. xlvii, pp. 75–81, 138–142. 1911.
JUKOVSKI, S.—New Metallurgical Oil Forges. *Gorn. Jurn.*, 1896, t. iii, pp. 14–51, 5 pls.
LENT, L. B.—Producer and Water Gas for Furnaces. (Forge furnaces equipped with gas and oil burners.) *Am. Machinist*, vol. xxxiv, pp. 692–696. 1911.
POPOV, N.—Oil Heating in Forges, Boilers, etc., in Moscow. *Gorn. Jurn.*, 1895, t. iii, pp. 1–30, 4 pls. See also under Boilers.

FUEL

AAGARD, H. B.—Liquid Fuel. Prize Essay, *Norwegian Govt.*, 1902.
ADAMS, E. E.—Fuel-Oil Installation on the Great Northern Railway. *Ry. and Engng. Rev.*, Dec. 9, 1911.
ADAMS, W. B.—Liquid Fuel. *J'l Soc. Arts*, vol. xvi, pp. 432–433. 1868.
ALEXIEEV, V.—Petroleum—Peat Fuel. *Zap. Imp. Russk. Tekhn. Obsch.*, g. xxxiii, Trudi, pp. 225–240. 1899.
ALLEST, J. D'.—De la Combustion des huiles Minerales et de leurs résidus. *Gén. Civ.*, t. viii, pp. 7–10, 19–22, 36–42. 1885.
ANDREEV.—Oil as Fuel. *Promischl*, t. i, pp. 227–246. 1864.
AUFHAUSER, DR.—Die Specificschen Eigenschaften und Unterschiede der festem und flüssigen Brennstoffe und ihre technische Bedeutung. *Glückauf*, April 19, 1913.
AYDON, H.—Liquid Fuels. *Proc. Inst. Civ. Eng.*, vol. iii, pp. 177–213. 1878.
BARFF, A.—Petroleum as Fuel. *J'l Soc. Arts*, vol. xxviii, pp. 761, 811–812. 1880.
BENDER, C.—Zur Prüfung des Brikettpeches. *Zeitschr. angew. Chem.*, bd. xviii, p. 954. 1905.
BERNEWITZ, M. W.—Fuel, Power and Water Supply of Tonopah, Nevada. *Min. and Sci. Pr.*, Dec. 14, 1912.
BEST, W. N.—The Science of Burning Liquid Fuel. *E. and M. J'l*, vol. lxxvii, pp. 771–772. 1904.
BOGATCHEV, V. I.—Report on the Combustion of Oil. *Zap. Kavk. Otd. Russk. Tekhn. Obsch.*, t. iii, p. 251. 1871.
BOHM, C.—On Crude Petroleum (Greek fire) Equipment for Purposes of Naval Warfare. *Trans. Inst. Nav. Archt.*, vol. xix, pp. 232–240. 1878.
BOOTH, W. H.—Notes on Liquid Fuel. *Proc. Assoc. Eng. in Charge*, No. 4, 1903.
———.—Oil Fuel vs. the Oil Engine. *Petrol. Wld.*, Dec., 1912.
BRAME, J. J. S.—Liquid Fuel and its Economic Aspects. *Petrol. Rev.*, vol. xxi, p. 237. 1909.
CAMPBELL, M. R.—Mineral Fuels. *Bull.* 471, *U. S. G. S.*
CERKEZ, S.—Briquets aus Lignite und Petroleum-rückständen. *Zeitschr. angew. Chem.*, bd. xviii, 1905, pp. 171–173.
CHAMBERS, J. C.—Petroleum Fuel. *Rep. Cons. U. S.*, vol. xxii, 1887, pp. 522–527.
DAY, DAVID T.—Reports in *Mineral Resources of the United States*, U. S. G. S., Washington, annual volumes from 1907 to 1912, inc.
———.—A Great Reservoir of Fuel Oil. *Eng. News*, Oct. 17, 1912.
DEANE, C. T.—The Burning of Crude Oil for Steam Purposes. *Petrol. Rev.*, vol. vi, pp. 385–397. 1902.
DUDLEY, C. B.—Fuel Oil. *J'l Frank. Inst.*, vol. cxxvi, pp. 81–95, 2 pls. 1888.
EINERT, K.—Das Rohöl und seine Verwertung als Heizmaterial. *Petrol. Zeitschr.*, bd. iv, pp. 613–618. 1909.
Electrical Review, London.—The Utilization of Crude Petroleum for Electric Power Production at El Centro, California. Dec. 8, 1911.
Electrical World.—Auxiliary Oil-burning Station for Southern California Station. (Long Beach plant of the Edison Co.) March 9, 1912.
ENNIS, W. D.—Burning Oil for Power and Heating. *Power*, vol. xxviii, pp. 943–947; 980–984. 1908.
FORSTNER, E. M.—The Use of Petroleum for Power Purposes. *Min. and Sci. Press*, vol. lxxxiv, pp. 130–131. 1902.

FRUCHT, J.—Use of Crude Oil as Fuel. *Montan. Zeit. Oesterr. Ung. Balkanl.*, bd. xv, pp. 45–46. 1908.
GROELING, A. E. VON.—Oils Distilled from Coal. *Petrol. Wld.*, May, 1913, p. 215.
GRUSZKIEWICZ, J.—Das Heizöl. *Năphta*, bd. xvi, pp. 93–95. 1908.
GULISCHAMBARCV, S. I.—Petroleum as Fuel. *Gorn. Jurn.*, 1880, t. ii, pp. 251–277.
———.—Consumption of Fuel for Business Purposes. Russ. Manuf. and Trade Dept., 1893.
———.—On the Oil Industries of America and Russia, with Special Reference to Texas and the Liquid Fuel Trade. *Petrol. Rev.*, vol. vii, pp. 81–88. 1902.
GWIGGNER, A.—Ueber den Einfluss der Flammentemperatur bei der Bewertung der Brennstoffe. *Stahl u. Eisen*, Mar. 6, 1913.
HALE, H.—Liquid Fuel Supply. (Western U. S.) *Cassier's Mag.*, vol. xl, pp. 3–16. 1911.
HARRIS, H. G.—Petroleum as a Producer of Energy. *Prof. Roy. Eng.*, vol. xvi, pp. 181–222. 1890.
HARTMANN, G.—Das Rohöl als Brennmaterial. *Petrol. Zeitschr.*, bd. v, pp. 380–383. 1910.
HAUTPICK, E. DE.—Oil as Fuel in Russia. *Min. Mag.*, pp. 872. 1910.
HECK, F.—Some Applications of Liquid Fuel. *Petrol. Rev.*, vol. xii, pp. 9–10. 1905.
HETZEL, F. V.—Changing from Oil Fuel to Coal. *Power*, Dec. 2, 1913.
HODGETTS, E. A. R.—Liquid Fuel. *Trans. Civ. Mech. Eng. Soc.*, 1888–1889, pp. 63–70. 1889.
HOUGH, E. S., and CRAWFORD, W. H.—Report of Recent Oil-burning Installations on the Pacific Coast. *Marine Engineering*, vol. vii, pp. 447–451. 1902.
HOWARD, J. L.—Fuel Conditions in California. (Pac. Coast Gas Assoc.) *Am. Gas Light J'l*, vol. lxxvii, pp. 256–258. 1902.
HUBBARD, C. L.—Liquid Fuel. *Power*, vol. xxix, pp. 400–401. 1908.
IZNAR, H. N.—Russian and Texan Oil Fuel. *Torg. Prom. Gaz.*, 1902.
KENNEDY, WM.—Oil as Fuel. *Southern Indust. Lbr. Rev.*, 1901.
LAKES, A.—The Fuel Resources of Colorado. *Am. Geol.*, vol. viii, pp. 7–19. 1891.
Lloyd's Register.—October, 1911.
LEWES, V. B.—Oil as Fuel. *Pet. Rev.*, vol. viii, pp. 8–10, 34, 83–85, 200–201, 224–226, 234–236. 1903.
———.—Fuel and its Future. *Cantor Lectures*, vol. viii, 1908.
LISENKO, K. I.—Outline of the Present Oil-production of Russia, and on the Use of Petroleum as Fuel. *Zap. Imp. Russk. Tekhn. Obsch.*, G. X, otd. i, pp. 353–449, map. 1876.
LOWE, L. P.—Practical Testing of Oils for Gas and Fuel Purposes. (Pacific Coast Gas Assoc.) *Am. J'l Gas Lighting*, vol. lxxv, pp. 405–407. 1901.
LUCKE, C. E.—Liquid Fuel Combustion. *Trans. Am. Soc. Mech. Eng.*, vol. xxiii, pp. 483–510. 1902.
MALCOLMSON, W. L.—Summary of the Advantages of Liquid Fuel. *Petroleum*, vol. ii, pp. 610–612. 1902.
Mechanical World.—The Advantages and Disadvantages of Liquid Fuel. Aug. 9, 1912.
NOBEL, L. E.—The Lamp Question and the Use of Oil as Fuel. *Zap. Imp. Russk. Tekhn. Obsch.*, g. xvi, otd. pp. 292–315, 3 pls. 1883.
NORTH, S. H., and EDWARDS, G. M.—The Economic Position of the Oil Fuel Question. *Engineer*, London, Dec. 29, 1911.
OLIPHANT, F. H.—Reports in *Mineral Resources of the United States*, U. S. G. S., Washington, prior to 1907.
ORDE, E. L.—Liquid Fuel. *Trans. N. E. Coast Inst. Eng., Shipbuilders*, vol. xvii, pp. 41–55, 69–71, 85–88. 1901.
ORR, H.—Petroleum Fuel. *J'l Frank. Inst.*, vol. lxxxiv, p. 27. 1872.
PAUL, B. H.—Use of Petroleum or Mineral Oil as Steam Fuel in Place of Coal. *Chem. News*, vol. x, pp. 292–293; vol. xi, pp. 63–65. 1864, 1865.
———.—On Liquid Fuel. *J'l Soc. Arts*, vol. xvi, pp. 400–410, 837. 1868.
———.—Petroleum as Fuel. *J'l Soc. Arts*, vol. xiii, pp. 100, 180. 1865.
PETTERSON, A.—Om flytande braüsle. *Jern. Kont. Ann.*, n.s., bt. lx, pp. 137–186. 1905.
PHILLIPS, WM. B., and WORRELL, S. H.—The Fuels Used in Texas. *Univ. Tex. Bur. Econ. Geol. and Techn., Bull.* 307, Dec., 1913.
PIERCE, JOHN.—Burning Crude Oil. *Prac. Eng.*, Dec. 15, 1912, p. 1223.
PIETRUSKY, K.—Ueber Rohölfeuerungen in den Vereinigten Staaten von Amerika. *Zeitschr. angew. Chem.*, bd. xxiv, pp. 1518–1520. 1911.
POL.—Objections to Replacing Coal by Oil. *Morsk. Sborn*, 1865, No. 4, otd. iii.

Popov, P. I., and Kudelin, G. P.—On the Use as Fuel of the Products of Baku Oil. *Zap. Imp. Russk. Tekhn. Obsch.*, Jan.-Feb., 1887, pp. 31-45.
Porn, M.—On the Advantages of Fuel Oil. *Rev. Petrolului*, t. i, pp. 195-197. 1908.
Prutzman, P. W.—Production and Use of Petroleum in California. *Bull. Calif. State Min. Bur.*, No. 32. 1904.
———.—Texas and California Crude Oils. *J'l Electr. Power and Gas*, 1904.
Rankine, W. J. M.—On the Economy of Fuel, Comprising Mineral Oils. *J'l Roy. United Serv. Inst.*, vol. xi, pp. 218-240. 1867.
Redwood, B.—Liquid Fuel. *Comp. Rend. Congr. Internat. Chim. Appl.* sess. 7; Organization, pp. 61-102. 1910.
Reed, W. W.—Fuel Oil. (S. W. Gas Assoc.) *Am. Gas Light J'l*, vol. lxxvi, pp. 695-697. 1902.
Richardson, C. J.—Petroleum as Steam Fuel. *J'l Roy. United Serv.*, vol. ix, pp. 70-74, pls. xi, xii. 1865.
———.—Petroleum as Steam Fuel. *Engineering*, vol. v, p. 60. 1868.
———.—Liquid Fuel. *J'l Soc. Arts*, vol. xvi, pp. 504-505. 1868.
———.—On the Use of Petroleum as Steam Fuel. *Chem. News*, vol. xi, p. 39. 1865.
Rigand, F.—Sur les Combustibles naturels. *Rev. Univ. Min.*, ser. 4, t. xxxi, pp. 145-174. 1910.
Robinson, F. C.—The Manufacture of Petroleum Products. *Proc. Eng. Club of Phila.*, April, 1913, p. 172.
Rodakowski.—Das Erdöl als Brennmaterial für die Industrie. *Naphta*, bd. x, pp. 135-136. 1902.
Rojestvenski, A. L.—Fuel Oil for Industrial Purposes. Russ. Ministr. Trade and Industry. 1907.
Rowland, J. F., Jr.—Fuel Oil. *J'l Frank. Inst.*, vol. clvi, pp. 139-141. 1903.
Samuel, M.—Liquid Fuel. *J'l Soc. Arts*, vol. xlvii, pp. 384-393. 1899.
Selwyn, J. H.—Petroleum as Steam Fuel. *J'l Roy. United Serv. Inst.*, vol. ix, pp. 62-70. 1865.
———.—Petroleum as Fuel. *Engl. Mech.*, vol. xxiv, p. 316. 1876.
Tachon, A.—Oil Fuel. *J'l Petrol.*, t. vi, pp. 381-385. 1906.
Tachon, Auguste.—Les Essais du Combustible Liquide en Amerique. *Le Pétrole*, May 5, 1913, p. 2.
Tarbutt, P. F.—Liquid Fuel. *Trans. Soc. Eng.*, 1886, pp. 193-216, 1 pl.
Trauschold, Reginald.—Oil as Emergency Fuel. *Pract. Eng.*, Jan. 15, 1913, p. 115.
Tweddle, H., Jr.—Crude Petroleum and its Products as Fuel. *E. and M. J'l*, vol. lxviii, pp. 459-460, 488-490, 517-520. 1899.
Viner, N.—Present Condition of Petroleum Firing in Russia. *Gorn. Jurn.*, 1889, t. iv, pp. 353-393.
Waters, C. E.—The Behavior of High-boiling Mineral Oils on Heating in the Air. *Bull. U. S. Bur. Stand.*, Oct., 1911.
Watts, W. L.—Oil as Fuel in Los Angeles County, Calif. *13th Rep. State Mineral Calif.*, pp. 662-664. 1896.
West, W. W. R.—Fuel Oil. *Electrician*, vol. xxx, pp. 302-303. 1902.
Weymouth, C. R.—Unnecessary Losses in Firing Fuel Oil and an Automatic System for Their Elimination. *Trans. Am. Soc. Mech. Eng.*, vol. xxx, pp. 797-835. 1908.
Wielezynski, M.—Die Heizölfrage in Boryslaw. *Pet. Zeitschr.*, bd. ii, pp. 485-487. 1907.
Williston, A. L.—Liquid Fuel for Power Purposes. *Eng. Mag.*, vol. xxv, pp. 237-252, 562-573, 721-730. 1903.
Wolff, M. E.—The Oil-burning Systems of Rumania. *Monit. Int. Pétrol. Roum.*, t. ix. 1908.
Zaloziecki, R.—Vergleichende Untersuchungen von Erdölbrennern. *Polyt. Journ.*, bd. cclxvii, pp. 265-274, 362-370. 1888.

Coal Tar

Burg, O.—Ueber Braunkohlen-Theer. *Ber. deutsch. Chem. Ges.*, bd. ix, pp. 1207-1209. 1876.

Burning Point

Attfield, J.—On the Igniting Point of Petroleum. *Pharm. Journ.*, ser. 2, 1867, pp. 318-325; 1871, ser. 3, vol. ii, p. 43.

BERNSTEIN, A.—Prüfung der Entzündlichkeit des Petroleums. *Sitz. Ver. Beförd. Gewerbfl.*, 1879, pp. 173–178.

———.—Petroleum-Prüfungs. *Apparat. Deutsch. Ind. Zeit.*, 1879, p. 517, pl. x.

BRAUN, O.—Ueber eine neuere Apparate zur Prüfung des Petroleums auf seine Entzündlichkeit. *Sitz. Ver. Beförd. Gewerbfl.*, 1881, pp. 212–216.

Flash Point

ALLEN, IRVING C., and CROSSFIELD, A. S.—The Flash Point of Oils. *Techn. Paper* 49, *Bur. Mines*, Washington, 1913. Also *Pet. Wld.*, Sept., 1913.

BARRAN, D'A. DE.—On M. Granier's Process for Lowering the Flash Point of Mineral Oils. *Compt. Rend.*, t. lxxiii, pp. 490–492. 1871.

BELL, C., STUART, D. R., and POWELL, A. E.—Discussion on the Flashing Point of Mineral Oils. *J'l Soc. Chem. Ind.*, vol. xii, pp. 991–994. 1893.

BREMER, G. J. W.—Der Entflammungspunkt von Petroleum. *Zeitschr. angew. Chem.*, bd. ix, pp. 494–497. 1896.

BULT, H. J.—The Flash Point of Petroleum Mixtures. *Petrol. Wld.*, vol. v, pp. 336–337. 1907.

CHEMIKER und TECHNIKER ZEITUNG.—Der Flammpunkt der Oele. Nov. 15, 1913.

WIEBE, H. F.—Die obere Brauchbarkeitsgrenze des Abel-Penskyschen Apparates und seine Vergleichung mit dem Penskyschen Flammenprüfer. *Petroleum*, May 21, 1913.

Fuel-Tar

ALLEN, B. J.—Some Notes on Oil and Tar Burning. *Am. Gas Light J'l*, vol. lxxii, pp. 482–486. 1900.

ANDOUIN, P.—See under Boilers, Stationary.

WHITAKER, A. D.—Tar and Tar Products., *Prog. Age*, Nov. 1, 1911.

Fuel-Tar Oil

BÜTOW and DOBBELSTEIN.—Untersuchung eines mit Teeröl betriebenen 480 P. S. Dieselmotors. *Glückauf*, June 22, 1912.

HAUSENFELDER, R.—Teerölverwertung für Heiz- und Kraftzwerke. *Stahl und Eisen*, May 9, 1912.

———.—Teerölverwertung fur Heiz- und Kraftzwerke. *Bitumen*, Feb. 16, 1913, p. 49.

RISPLER, A.—Heizung mit Teerölen. *Oesterr. Zeitschr. Berg.-Hütt.*, bd. liii, pp. 548–550, pl. xvii. 1905.

SCHÖMBURG.—Verwendung des Teeröls für Kraftmaschinenzwerke und industrielle Feuerungs Anlagen. *Berg. u. Hüttm. Rundschau*, Dec. 20, 1912, p. 64.

FURNACES

ALTUKHOV, M.—Heating Furnaces with Oil and its Residue. *Tekhnik.*, 1883, No. 16, p. 6.

ASHCROFT, A. G.—Experiments on a Method of Measuring the Air or Gas-supply to Engines and Furnaces. *Proc. Inst. Civ. Eng.*, vol. clxxiii, pp. 289–297. 1908.

BEST, W. N.—Oil Fired Furnaces. *Trans. Amer. Fndrym. Assoc.*, 1911, pp. 421–424.

BRASSEUR, M.—L'application du chauffage a l'huile lourde aux fours métallurgiques. *Rev. de Métall.*, Aug., 1913.

CALDWELL, J. K.—Coal Dust and Petroleum Furnace. *Sci. Am. Supp.*, vol. i, p. 125, 1876.

CRANE, W. E.—Crucible Furnaces for Burning Petroleum. *Trans. Am. Soc. Mech. Eng.*, vol. xv, pp. 307–312, 1894.

KNUTSEN, J. B. M.—Industrial Furnaces. *Austral. Min. Stand.*, May 30, 1912.

LANG, HERBERT.—Oil-burning in Furnaces. *Min. and Sci. Press*, July 12, 1913.

LENNINGS, P.—Fortschritte auf dem Gebiet der Oelfeuerung unter besonderer Berucksichtigung der Oelschmelzöfen System Buess. *Giess. Zeitung*, May 15, 1913.

NOBEL, L. E.—On the Extended Use of Oil Residues in Furnaces, without Spraying. Moscow. 1882.

Power.—Oil Burning with Different Settings. Feb. 6, 1912.

RAMSDEN, J. C.—Improvement in Hydrocarbon Furnaces. *Sci. Am. Suppl.*, vol. i, p. 125. 1876.

SAVINE, P. P.—Remelting of Foundry Pig-iron with Petroleum. *Gorn. Jurn.*, 1905, t. i, pp. 82–103.

SURJITSKI, S.—Thermal Study of the Martin Oil Furnace. *Gorn. Jurn.*, 1901, t. iii, pp. 79–127.

UREN, S., HINKINS, and CAMP, J. G.—Best Form of Oil Furnace for Locomotive Shop Work and Burners for Same. *Rep. Railr. Blacksm. Assoc. Conv.*, xii, pp. 101–108. 1904.

VENATOR, WILLIAM.—Ueber einem Schmelzofen mit Oelfeuerung. *Giess. Zeit.*, June 1, 1912. See also under Burners.

WATERS, ALBERT L.—Experiments with an Oil-burning Shaft Furnace. *E. and M. J'l*, Aug. 2, 1913.

WEYMOUTH, C. R.—Furnace Arrangements for Fuel Oil. *Trans. Am. Soc. Mech. Eng.*, vol. xxxiii, pp. 879–882. 1911.

WURTZ, H.—The Eames System of Furnace Working with Petroleum. *Am. Chem.*, vol. vi, pp. 94, 102. 1876.

Annealing and Heating

LORD, J.—Cost of Running Annealing and Heating Furnaces. *Iron and Coal Tr. Rev.*, March 14, 1913.

Assaying

BOWMAN, F. C.—The Use of Crude Oil for Fire Assaying. *Proc. Color. Sci. Soc.*, vol. vii, pp. 341–346. 1904.

BRENT, C.—Notes on Oil Furnaces for Assaying and Melting. *J'l Can. Min. Inst.*, vol. v, p. 288. 1902.

COLLINS, B. R. T.—A Two-muffle Oil-burning Assay Furnace. *Austral. Min. Standard*, vol. xiv, p. 12, 1911.

Blast

LANG, HERBERT.—Blast-furnace Smelting with Crude Oil. *Min. and Sci. Press*, Feb. 8, 1913, p. 248.

Crucible

Iron Trade Review.—Crucible Process for Making Steel Castings (Milwaukee Type of Furnace). Oct. 26, 1912.

Frame Plate

GATEWOOD, R. D.—Oil-burning Frame Plate Furnace. *Am. Mech.*, July 18, 1912

Glass

MALISCHER, I.—Experiments on the Use of Petroleum Fuel in Glass-melting Furnaces in the Sophy Glass Works at Astrakhan. *Zap. Imp. Russk. Tekhn. Obsch.*, g. xxv, pp. 98–102, 1 pl. Dec., 1891.

Foundry

ALEXIEEV, P. P.—Foundry Furnaces Heated by Luminous Gas and Volatile Oil. *Gorn. Jurn.*, 1866, t. iii, pp. 295–309.

Gordon-Prall

Iron Trade Review.—April 25, 1912.

Martin's Steel

BYSTROM, A.—Der russische Martinofen mit Oelfeuerung. *Zeitschr. Berg.-Hütt.*, bd. i, pp. 34–36. 1902.

Open-Hearth

BYSTROM, A.—The Use of Liquid Fuel in Open-hearth Furnaces in Russia. *Bihang Jernkont. Ann.*, 1901, pp. 301–309.

MACGREGOR, WALTER.—Design of Oil-fired Open-hearth Furnaces. *Ir. Trd. Rev.*, Nov. 16, 1911. *Mech. Engr.*, Jan. 5, 1912.

PAWLOFF, M. A.—Dimensions of Open-hearth Furnaces, Gas or Oil Fired. Abstract of paper in *Stahl und Eisen*. *Iron and Coal Trds. Rev.*, Jan. 26, 1912.

REDDY, B. H.—The Operation of Small Open-hearth Furnaces. *Foundry*, March, 1912.

Pottery

Alexander.—Die Verwendung flüssigen Feureungsmaterialien in der Gas- und Keramischen Industrie der Vereinigten Staaten von Nord Amerika. *Sprechsaal*, bd. xxxvii, pp. 525–527. 1904.

Reverberatory

Brass World.—The "Gamm" Oil Reverberatory Furnace for Melting Nickel. Feb., 1913.

Savine, P. P.—Reverberatory Petroleum Furnace for Foundry Purposes. *Gorn. Jurn.*, 1896, t. ii, pp. 1–12, 2 pls.

Shelby, C. F.—Oil Burners for Reverberatory Furnaces. *E. and M. J'l*, vol. lxxxix., pp. 31–32. 1910. See also under Burners.

Riveting

Allcut, E. A.—Oil furnaces for Rivet Heating. *Univ. Birmingham Eng. Min. Journ.*, vol. vii, pp. 150–153. 1909.

Roasting

Willard.—Ore Roasting with Petroleum Fuel. *Min. and Sci. Press*, vol. xxii, Nos. 10 and 16. 1871.

Rotary

Gulischambarov, S. I.—L. E. Nobel's Oil-sprinkler for Rotary Furnaces. *Tekhnik*, 1882, No. 2.

Siemens-Martin Steel

Giesserei Zeitung.—Ueber die Konstruction und den Betrieb von Siemens-Martinöfen mit Oelfeuerung. Feb. 1, 1913, p. 81.

Smelting

Abraham, A.—Emploi des Residues de Naphthe dans les usines siderurgiques de Russie. *Gén. Civ.*, t. xl, pp. 9–11. 1901.

Batty, W.—Petroleum Residue as Fuel for Smelting Furnaces. *Polyt. Rev.*, 1876, p. 51.

Gulischambarov, S. I.—The Use of Petroleum for Metallurgical Purposes. 1888.

Hamilton, E. H.—The Use of Oil for Smelting. *E. and M. J'l*, vol. xci, pp. 224–225. 1911.

Hughes, H. H., and Hale, H.—Crude Petroleum as a Reducing Agent for Zinc Ores. *J'l Ind. Eng. Chem.*, vol. i, pp. 788–789. 1909.

Jacobs, E.—Blast-furnace Smelting with Oil. *E. and M. J'l*, vol. xcii, p. 434. 1911.

Laforest, de.—Emploi de pétrole pour la fabrication du fer. *Ann. Mines*, sér 7, t. ii, pp. 557–558. 1872.

Van der Ropp, A.—The Use of Crude Oil in Smelting. *E. and M. J'l*, vol. lxxv, pp. 81–82. 1903.

Venator, Wilhelm.—Ueber Oelfeurung mit besonderer Berucksichtigung der oelgefeuerten Schmelzöfen und Oelbrenner für den Giessereibetrieb. Serial. *Giess. Zeit.*, Feb. 15, 1913.

Weiller, P.—Das Heizöl im Hüttenbetriebe. *Pet. Zeitschr.*, bd. iii, pp. 510–514. 1908.

Steel Heating

Spillman, Harry C.—Kerosene for Steel-heating Furnaces. *Mach.*, N. Y., Oct., 1913.

Gasoline

Burrell, Geo. A., and Siebert, Frank M.—The Condensation of Gasoline from Natural Gas. *Chem. Engr.*, Sept., 1913.

Hirshfeld, C. F.—Production of Gasoline from Natural Gas. *Eng. Mag.*, Sept., 1912.

Peterson, F. P.—Squeezing Gasoline out of Natural Gas. *Sci. Am.*, Aug. 17, 1912.

Gas Works

Adams, H. E.—Economy of Firing Benches with Crude Oil. *Am. Gas Light J'l*, vol. lxxv, p. 365. 1901.

Armstrong, H. E.—On the Manufacture of Gas from Oil. *J'l Soc. Chem. Ind.*, vol. iii, pp. 462–468, 1884.

Bower, G.—Gas from Petroleum Oil and from Wood and Peat Enriched with Oil. *J'l of Gas Light.*, vol. xii, pp. 516–517. 1863.

Burkhart, H. W.—Oil Situation from a Gas Man's View-point. *Progress. Age*, vol. xxviii, pp. 960–962. 1910.

Clements, J.—Device for Using Crude Oil for Bench Fuel. Device for Using Crude Oil for Gas Enrichment. *Am. Gas Light J'l*, vol. lxxxv, pp. 367–368. 1901.

Gregory, O. M.—The Use of Crude Oil for Firing Benches. *Am. Gas Light J'l*, vol. lxxv, pp. 363–365. 1901.

Powers, R. M.—The Use of Crude Petroleum for Firing Benches. (Pacific Coast Gas Assoc.) *Am. Gas Light J'l*, vol. lxxiii, pp. 207–208. 1900.

Schilling.—Die Beleuchtung mit Gas aus Petroleum Rückstanden in der Locomotive Fabrik von Krauss & Co. zu München. *J'l Gas-beleucht.*, bd. x, pp. 152–157, 1867.

Heating Power

Albrecht, M.—Ueber den Brennwerth des russichen Petroleums. *Chem. Rev. Fett-Harz. Ind.*, bd. v, pp. 189–193. 1898.

Alexieev, V.—Calorific Value and Composition of Russian Mineral Combustibles. *Gorn. Jurn.*, 1886, t. iii, pp. 446–487; 1887, t. i, pp. 87–121; 1888, t. i, pp. 124–143; t. iv, pp. 61–99.

Atwater, W. O., and Snell, J. F.—Description of a Bomb-calorimeter, and Method of its Use. *J'l Am. Chem. Soc.*, vol. xxv, pp. 659–699. 1903.

Berthelot, M. P. E., and Recourae.—Bombe calorimetrique. *Compt. Rend.*, t. civ, pp. 875–880.

Bieliamin, M.—The North American Oil Industry. *Izv. Obsch. Gorn. Ijen.*, 1894, Nos. 5–6, pp. 15–27.

Church, A. T.—Notes on Fuel Oil and its Combustion. *J'l Am. Soc. Naval Engrs.*, vol. xxiii, pp. 795–831. 1911.

Coleman, J. J.—Sur l'inflammabilité relative des huiles d'origine animale, végétale et minérale. *Bull. Soc. Ind. Malh.*, t. xlvi, pp. 104–107. 1876.

Fenn, R. W.—Calorific Value of California Fuel Oil. *Eng. News*, vol. lxi, pp. 516–518. 1909.

Fischer, F.—Apparat zur Bestimmung der Verbrennungswärme. *Ber. deutsch. Chem. Ges.*, bd. xii, pp. 1694–1696. 1879.

Gruszkiewicz, J.—Ueber die Verbrennungstemperatur des Rohöls. *Naphta*, bd., xvi, pp. 68–69. 1908.

Hempel, W.—Ueber die Bestimmung der Verbrennungswärme der Heizmaterialien. *Zeitschr. angew. Chem.*, bd. ix, pp. 350–352. 1896.

Huntley, G. N.—The Accuracy Obtainable in Fuel Calorimetry. *Chem. Eng.*, vol. xiii, pp. 147–152. 1911.

Inchley, W.—Calorific Value of Solid and Liquid Fuels. *Engineer*, vol. cxi, pp. 155–156. 1911.

Kharitchkov, K. V.—Elementary Composition and Heating Power of the Petroleum Residues of Grozni. *Gorn. Jurn.*, 1898, t. i, pp. 352–355.

Kroker, K.—Ueber die Bestimmung des nutzbaren Verbrennungswärme der Heizmaterialien. *Zeitscher. Ver. Rübenz. Ind.*, bd. xlvi, pp. 177–194. 1896.

Le Conte, J. N.—The Relative Value of Light Oil as Compared with Fuel Oil. *J'l Am. Soc. Mech. Eng.*, vol. xxxiii, pp. 876–879. 1911.

Lisenko, K. I.—Calorific Powers of Petroleum. *Jurn. Russk. Phiz. Khim. Obsch.*, t. ix, otd. i, pp. 290–292. 1877.

Parr, S. W.—The Peroxide Calorimeter as Applied to European Coals and Petroleum. *J'l Am. Chem. Soc.*, vol. xxiv, pp. 167–171. 1902.

Phillips, Drury McN.—See Udden, J. A.

Phillips, Wm. B.—Texas Petroleum. *Bull. No. 1, Univ. Tex. Min. Surv.*, 1901.

———.—The Quality of the Fuel Oils Sold in Texas. *Fuel Oil J'l*, vol. v, No. 2, Feb., 1914.

——— and S. H. Worrell.—The Fuels Used in Texas. *Bull. Bur. Ec. Geol. and Techn. Univ. Texas*, No. 307, Dec., 1913.

Rankine, W. J. M.—On the Estimation of the Evaporative Power of Fuel. *Proc. Phil. Soc. Glasgow*, vol. v, pp. 123–126. 1868.

SCHPAKOVSKI.—Comparative Value for Steam Boilers of Coal, Turpentine and Petroleum. *Morsk. Sborn,* 1866, pp. 173–180. See also under Boilers.

SHERMAN, H. C., and KROPFF, A. H.—The Calorific Power of Petroleum Oils and the Relation of Density to Calorific Power. *J'l Am. Chem. Soc.,* vol. xxx, pp. 1626–1631. 1908.

SHERMAN, H. C., and SNELL, J. F.—On the Heat of Combustion as a Factor in the Analytical Examination of Oils; and the Heats of Combustion of some Commercial Oils. *J'l Am. Chem. Soc.,* vol. xxiii, pp. 164–172. 1901.

SLOSSEN, E. E., and COLBURN, L. C.—The Heating Value of Wyoming Coal and Oil. *Sch. of Min., Univ. Wyo., Bull. No.* 2, 1895.

UDDEN, J. A., and PHILLIPS, DRURY MCN.—Reconnaissance Report on the Oil and Gas Fields of Wichita and Clay Counties, Texas. *Bur. Ec. Geol. and Techn., Univ. of Tex., Bull.* 246, 1912.

WEINWURM, S.—Relation of Flashing and Combustion Temperatures in mineral oils. *Mitth. Chem. Inst. Techn. Unters. Wien.* 1892.

WORRELL, S. H.—See Phillips, Wm. B.

LOCOMOTIVES

Engineering.—The Sulzer-Diesel Locomotive. Sept. 5, 1913.

Engineering News.—An Industrial Locomotive Driven by a Crude Oil Engine. (Nitrate industry, Chili.) Jan. 9, 1913.

———.—The First Diesel Locomotive. Oct. 2, 1913.

LEROUX, E. P.—Les Locomotives avec Moteur à Benzine à cylindres multiples. *La Revue Noire,* May 25, 1913.

Railway Gazette, Lond.—Diesel Locomotive Built by Sulzer Bros. Oct. 3, 1913.

Railway Master Mechanic.—Gasoline Freight and Switching Locomotive. Sept., 1913.

Scientific American Supplement.—The First Diesel Locomotive. Sept. 20, 1913.

Zeit. des Ver. deutscher Ing.—Die erste Thermo-Lokomotiv. Aug. 23, 1913.

Mining

AUSTIN, K.—Mining Locomotives and Liquid Fuel: Their Probable Influence on South African Labor Troubles. *Journ. Transvaal. Inst. Mech. Eng.,* vol. ix, No. 1, 1910.

HODGES, R. O.—Gasoline Motors in Coal Mines. Paper before W. Va. Coal Min. Inst. 1913.

KING, A. F.—Use of Gasoline Motors in Coal Mines. *Min. and Sci. Press,* Sept. 20, 1913.

SCHOLZ, CARL.—Gasoline Mine Locomotives in Coal Mining. *Coll. Engr.,* Oct., 1913.

MISCELLANEOUS

CARACRISTI, C. F. Z.—The World's Production of Petroleum. *Min. Ind.,* vol. viii, pp. 454–466. 1900.

CHIVOT-NAUDÉ.—Rapport sur l'huile de pétrole. Ses propriétés et ses Applications. *L'Invention,* ann. xx, pp. 43–52. 1866.

GULISCHAMBAROV, S. I.—Petroleum and its Products in the World's Industry and Trade. *Petrol. Rev.,* vol. xiii, pp. 43–44, 63–64. 1905.

HINRICHSEN, F. W.—Bericht ueber den VI Kongress des Internationalen Verbandes für die Materialprüfungen der Technik. New York, 1912. *Zts. Electrochemie,* May 15, 1913, p. 409.

LAZARE.—L'Emploi du Combustible Liquide sur le Monde. *Journ. Petrol.,* t. xi, pp. 194–195. 1911.

LIWEHR, EUGEN.—Neuerungen auf dem Bebiete der thermischen Erdölförderung. *Petroleum,* Oct. 15, 1913.

Oil Age.—Regulations for Leasing Canadian Government Oil and Gas Lands. Nov. 28, 1913.

Pétrole, Le.—Les Valeurs de Pétrole sur le Marché Anglais. Aug., 1913.

Petroleum.—Der Monopolgesetzentwurf nach den Beschlüssen der Leuchtölkommission. April 16, 1913.

———.—Die Entwickelung der Monopolfrage. April 16, May 7, May 21, June 4, June 18, July 2, 1913.

———.—Die Verkehrs- und Handelsvorschriften für das Petroleum in den einzelnen Ländern. May 21, June 4, Nov. 5, 1913.

Petroleum.—Entwurf einer Polizeiverordnung über Minerelmischungen in Deutschland. July 2, 1912.
Petroleum World, London.—The Origin of Petroleum. Sept., 1913.
REDWOOD, B.—Petroleum and its Products. *Cantor Lectures,* vol. iii. 1886.
ROGERS, H. D.—Coal and Petroleum. *Harper's Mag.,* vol. xxvii, p. 259. 1863.
THÖRNER, W.—Das Petroleum, seine Gewinnung, Verwerthung und Verfälschung. *5th Jahresb. Nat. Ver. Osnabrück,* pp. 29–54. 1883.
WATERS, C. E.—Behavior of High-boiling Mineral Oils on Heating in the Air. *J'l Ind. Eng. Chem.,* vol. iii, pp. 233–237. 1911.
YALOVETSKI, B.—Water, Fuel and Steam Boilers, Liquid and Gas Fuel, Crude Coal Tar and Petroleum. *Jurn. Minist. Put. Soobsch.,* 1879, t. i, pp. 341–352.

Foreign Countries—China

Chemische und Technische Zeitung.—Petroleumfundstätten in China. May 15, 1913, p. 79.

England

Petroleum World.—Oil in the British Empire. March, 1913, p. 121.

Europe

TWEDDLE, H., JR.—The Petroleum Industries of Europe. *Engineering,* vol. xli, pp. 99–100, 149–152, 193–194, 239–243, 289–290, 341–342. Maps and Sections. 1886.

India

CHOLMELEY, N. G.—The Oil Fields of Burma. *Petrol. Wld.,* May, 1913, p. 221. *J'l Soc. Arts,* May 16, 1913, p. 639.
WHITE, H. T.—Report on the Oil Wells of Burma. (Blue Book.) 1888.

Mexico

BALL, S. H.—The Tampico Oil Field, Mexico. *E. and M. J'l,* vol. xci, pp. 959–961. 1911.
BURR, G. A.—Petroleum in Texas and Mexico. *E. and M. J'l,* vol. lxxi, 1901, pp. 687–688.
BUSTAMENTE, M.—Informe sobre los criaderos carboniferos de las Huastecas. *An. Min. Fom. Rep. Mex.,* t. vii, pp. 538–547. 1882.
———.—Ligero estu dio sobre los pozos de "El Ebano" explotados por la Mexican Petroleum Co. *Bol. Soc. Geol. Mex.,* t. ii, pp. 111–131, pl. 1906.
D'ANTHONAY, A. J.—Le Pétrole au Mexique. *Journ. Petrol.,* t. x, p. 151. 1910.
Fuel Oil Journal.—Mexican Crude Replacing the Domestic Product along the Gulf Coast. Vol. ii, No. 2, pp. 3–4, Aug., 1912.
HORNADAY, W. D.—Petroleum in Mexico. *Min. and Eng. Wld.,* 1911.
MAGILL, S. E.—Oil Resources of Mexico. *U. S. Cons. Rep. No.* 317, pp. 53–55. 1907.
MENNEL, J. L.—Oil in Mexico. *Min. Mag.,* vol. ii, pp. 448–450. 1910.
Mining and Engineering World.—Importance of Mexico as a Petroleum Producer. June 22, 1912.
———.—Operations of the Mexican Petroleum Company. May 10, 1913, p. 916.
SKERTCHLY, S. A. R.—Oil in Mexico. *Min. Mag.,* vol. iii, pp. 283–286. 1910.
WILSON, H. W.—Reports for the years 1907–1910 on the Trade of the Consular District of Tampico. *Dipl. Cons. Rep. Ann.,* ser. Nos. 4051, 4215, 4663. 1908, 1909, 1910.
WOOD, H. L.—Oil Fields of Mexico. *Oil and Gas J'l,* vol. ix, Nos. 43–45. 1911.

Russia

CHAMBERS, C. J.—The Russian Petroleum Trade. *U. S. Cons. Rep.,* vol. lxix, pp. 175–216. May, 1902.
HAUTPICK, E. DE.—Russian Oil Fields To-day. *Min. Journ.,* Oct. 5, 1912.
———.—How the Russian Petroleum Market is Regulated. *Min. Journ.,* Oct. 5, 1912.
WISCHIN, R. A.—Die russiche Erdölindustrie am Anfage unseres Jahrhunderts. *Zeitschr. angew. Chem.,* bd. xiii, pp. 313–318. 1900.

South America

CARACRISTI, C. F. Z.—Coal and Petroleum in Colombia. Bur. Am. Republics, *Spec. Bull.,* pp. 23. Washington, 1893.

Caracristi, C. F. Z.—Colombia. A New Field for the Development of Coal and Petroleum. *Ir. and Coal. Tr. Rev.*, vol. lvii, pp. 349–351. 1898.

United States of America—California

Anderson, Robt.—Experts and the Productive Area of California Oil Fields. *E. and M. J'l*, vol. lxxxix, p. 901. 1910.
Bennett.—Reports for the years 1902, 1905, and 1906, on the Trade, etc., of the States of California, Nevada, Utah, and Arizona. *Dipl. Cons. Rep. Ann.*, ser. Nos. 2988, 3564, 3782. 1903–1907.
Buchner, G.—Erdölverwendung in California. *Bayer. Ind. Gewerb.*, bd. xli, pp. 160–161. 1909.
Cooper, A. S.—Southern California Petroleum. *Min. and Sci. Press*, vol. lxxvii, p. 373. 1898.
Harrison, W. J.—Consumption of Coal and Oil in California. 1902–1903.
Heurteau, Ch. E.—L'Industrie du Pétrole en California. *Ann. des. Mines*, 10th ser., vol. iv. 1903.
Martin, A. H.—California Oil Situation. *Min. and Eng. Wld.*, Feb. 8, 1913, p. 306.
Prutzman, P. W.—History and Geology of California Oil-fields. *Min. and Engng. Wld.*, June 22, 1912.
Requa, M. L.—Present Conditions in the California Oil-fields. *Min. and Sci. Press*, Nov. 18, 1911.
———.—Present Conditions in the California Oil-fields. *Bull. Am. Inst. Min. Engrs.*, April, 1912.
Rickard, T. A.—Coalinga: A California Oil-field. *Min. Mag.*, Oct., 1912.
Storms, W. H.—Growth of the Petroleum Industry in California, map. *Min. and Engng. Wld.*, June 22, 1912.
Watts, W. L.—The Gas and Petroleum-yielding Formations of the Central Valley of California. *Bull. Calif. State Min. Bur.*, *No.* 3, pp. 100, maps and pls., 1894.
———.—Petroleum in California. *13th An. Rep. State Min. Calif.*, pp. 570–593. 1896.
Wishon, A. E.—Electrical Energy in the Oil-fields of California. *J'l Elec. P. and G.*, April 26, 1913, p. 375.
Wolf, J. H. G.—Production and Prices in the California Oil-fields. *Min. and Sci. Press*, Jan. 6, 1912.
———.—Production and Allied Statistics, California Oil-fields. *Min. and Sci. Press*, Sept. 28, 1912.
Young, W. G.—Present Outlook for the Oil Industry in California. *E. and M. J'l*, vol. lxxii, p. 664. 1901.
———.—The Present Condition of the Oil Industry of California. *E. and M. J'l*, vol. lxxiv, pp. 545–546 1902.

United States—General

Burkart.—Das Petroleum und seine Produktion in Nord Amerika. *Berg-Hütt. Zeit.*, bd. xxix, pp. 373–376. 1870.
Burroughs, W. G.—The Petroleum Fields of the United States. *E. and M. J'l*, vol. lxxxix, 1911, pp. 921–924.
Day, David T.—The New Oil Fields of the United States. *Am. Rev. of Rev.*, June, 1901.
———.—The Petroleum Resources of the United States. *Am. Rev. of Rev.*, Jan., 1909.
———.—Production of Petroleum in the United States in 1911. *Min. and Engng. Wld.*, Sept. 28, 1912.
Hager, Lee.—The Future Oil Supply of the United States, map. *Fuel Oil J'l*, vol. ii, No. 3, pp. 37–41, Sept., 1912.
Mineral Industry, N. Y.—Annual Volumes, 1892 to 1912, inc.
Mining and Engineering World.—Production of Petroleum in the United States, 1911. Jan. 27, 1912.
———.—Petroleum Industry in the United States in 1912. Jan. 25, 1913, p. 157.
Peckham, S. F.—Report on the Production, Technology and Uses of Petroleum and its Products. (Tenth U. S. Census.) *Quart. Rep. U. S. Bur. Statistics.*, vol. x, 1888.
———.—Petroleum. Eleventh Census Rep., Washington, 1892.
Walsh, Geo. E.—American Petroleum Possibilities. *Cassier's Mag.*, Dec., 1902.
Wildman, R.—American, Russian and Sumatra Petroleum. *Rep. U. S. Cons.*, vol. xl, pp. 456–459. 1892.

WOOD, H. L.—Fuel Oil Conditions Changing in the Central West. *Fuel Oil J'l*, vol. ii, No. 6, pp. 50–51, December, 1912.

Louisiana

HARRIS, G. D.—Oil and Gas in Louisiana, with a Brief Summary of Their Occurrence in Adjacent States. *Bull. No.* 429, *U. S. G. S.*, 1910.
HAYES, C. W.—Oil-fields of the Texas-Louisiana Gulf Coastal Plain. Paper in *Bull. No.* 213, *U. S. G. S.*, 1903.
——— and WM. KENNEDY.—The Texas-Louisiana Oil-fields. *Sci. Am. Supp.*, Nov. 15, 1902.
WOOTON, PAUL.—History and Developments of Louisiana's Oil-fields. *Min. and Engng. Wld.*, June 22, 1912.

Oklahoma

GOULD, CHAS. N.—Petroleum and Natural Gas in Oklahoma. *Econ. Geol.*, Dec., 1912, p. 719 *et seq.*
WITTICH, L. L.—Petroleum in Oklahoma. *Min. and Min.*, vol. xxxii, pp. 291–294, 1911.

Southern States

CARACRISTI, C. F. Z.—Southern Petroleum and the Fuel Market. *Manuf. Rec.*, Feb. 20, 1902.
DAY, DAVID T.—Broad Survey of Southern Potentialities in Mineral Development. *Manuf. Rec.*, Jan. 7, 1909.
———.—The South's Oil Contribution. *Manuf. Rec.*, Jan. 18, 1911.
———.—Vast Storehouse of Fuel in Southern Petroleum and Natural Gas. *Manuf, Rec.*, Feb. 22, 1912.
OLIPHANT, F. H.—Import of the Production of Southern Petroleum. *Manuf. Rec.*, Feb. 22, 1902.

Texas

BURR, G. A.—Petroleum in Texas and Mexico. *E. and M. J'l*, vol. lxxi, pp. 687–688. 1901.
Fuel Oil Journal, Houston, Texas.—Files of, from vol. i, No. 1, October, 1911, to vol. v, No. 1, January, 1914.
HAYES, C. W.—See under Louisiana.
HILL, R. T.—Beaumont Oil Fields, with Notes on Other Oil Fields of the Texas Region. *Trans. Am. Inst. Min. Engrs.*, vol. xxxiii, pp. 363–405. 1902.
KENNEDY, WM.—See under Louisiana.
LUCAS, A. F.—The Great Oil Well near Beaumont, Texas. *Am. Manuf.*, July 11, 1901.
———.—The Great Oil Well near Beaumont, Texas. *Trans. Am. Inst. Min. Engrs.*, vol. xxxi, pp. 362–374, 1029–1032. 1901.
———.—Résumé of the Texas Oil Fields. *Comp. Rend. Congr. Internat. Pétrole*, sess. 3, t. ii, pp. 341–364. 1910.
MALCOLMSON, W. L.—Spindle Top, near Beaumont, Texas. *Petroleum*, vol. ii, 1902, pp. 610–612.
Manufacturers' Record.—Significance of the Texas Oil Field. April 11, 1901.
MILLER, THOS. D.—Recently Developed Oil Fields of Texas. *E. and M. J'l*, vol. lxv, 1898, pp. 734–735.
———.—The Texas Oil Fields. *Am. Gas. Light J'l*, vol. lxxxiii, 1905, pp. 86–91.
PERCEVAL, C. A. S.—Report for the year 1909 on the Trade and Commerce of the Consular District of Galveston. *Dipl. Cons. Rep. Ann.*, ser. No. 4425. 1910.
———.—Petroleum Output in Texas. *B'd of Trade J'l*, vol. lxxiii, p. 527. 1911.
PHILLIPS, DRURY MCN.—See Udden, J. A.
PHILLIPS, WM. B.—Texas Petroleum. *Univ. Tex. Min. Surv. Bull. No.* 1. 1901.
REAVIS, H. S.—Petroleum in Southwestern Fields. *Manuf. Rec.*, Jan. 3, 1907. See also editorials in *Fuel Oil Journal.*
STOEK, H. H.—The Beaumont, Texas, Oil Field. *Min. and Min.*, vol. xxiii, pp. 490–492. 1903.
UDDEN, J. A., assisted by Drury McN. Phillips.—Reconnaissance Report on the Geology of the Oil and Gas Fields of Wichita and Clay Counties, Texas. *Bur. Ec. Geol. and Techn., Univ. Tex., Bull.* 246. 1912.
WILLEY, DAY ALLEN.—New Texan Oil Deposits. *Sci. Amer.*, Jan. 30, 1904.

PIPE LINES

EDDY, LEWIS H.—California Oil Pipe Lines. *E. and M. J'l*, June 28, 1913.

Fuel Oil Journal.—California Regulations. Vol. iv, No. 6, p. 77, Dec., 1913.

———.—Concession in Vera Cruz, Mexico. Vol. ii, No. 3, pp. 5–7, Sept., 1912.

———.—De La Vergne Crude Oil Engines for Standard Oil Co. of Louisiana. Vol. iv, No. 5, p. 53, Nov., 1913.

———.—Pipe Line and Refinery Construction in Texas in 1912. Vol. iii, No. 2, p. 40, Feb., 1913.

INTERSTATE COMMERCE COMMISSION.—Common Carriers. Decision, 1912.

SIEMENS, G. R. v.—Mannesman-Rohleitung von 100 at. Betriebsdruck für flüssige Brennstoff in Ural. *Sitz. Ver. Beförd. Gewerbefl.*, bd. lxx, pp. 172–173, 1891.

STROUD, B. K.—Oil Pipe Lines in California. *Eng. News*, March 13, 1913, p. 500.

VOISLAV, S. G.—Organization of Pipe Lines. *Zap. Imp. Russk. Tekhn. Obsch.*, g. xiii, otd. i, pp. 237–274. 1879.

Zts. Internat. Ver. Rohringgen.—Das Schweissen von pipe lines für hohen Druck. May 1, 1913, p. 106.

PUMPING

BOWIE, C. P.—Pumping California Oil. *Oil Age*, 1911.

ISAACS, J. D.—A New Method for Pumping Heavy Crude Fuel Oil or Other Thick Viscous Fluid. *Eng. News*, vol. lv, pp. 640–641. 1906.

PRODUCER GAS

Fuel Oil Journal.—The Tate-Jones. Vol. iv, No. 3, pp. 68–69, Sept., 1913.

GRINE, H. A.—Making Producer Gas from Crude Oil. *Min. and Sci. Pr.*, vol. ciii, pp. 381–382. 1911.

JONES, E. C.—Producer Gas from Crude Oil. *Trans. Am. Soc. Mech. Eng.*, vol. xxxiii, pp. 903–906. 1911.

LAZAREV, P.—Oil-gas Producer. *Zap. Imp. Russk. Tehkn. Obsch.*, g. xxix, Trudi, pp. 337–374. 1905.

RESERVOIRS AND STORAGE

Engineering and Mining Journal.—Tankage Capacity of Beaumont Oil Fields. May 10, 1902.

Fuel Oil Journal.—Oil Reservoirs at San Luis Obispo, California. Perhaps the largest in the world. Vol. i, No. 6, pp. 34–35, April, 1912.

OATMAN, F. W.—A Concrete Reservoir for Storage of Petroleum, near Coalinga, California. *Min. and Engng. Wld.*, Nov. 18, 1911.

U. S. NAVY.—Storage Capacity. *Fuel Oil Journal*, vol. iv, No. 5, p. 9, Nov., 1913. See also *Min. Res. U. S.*, U. S. G. S., an. vols.

WHITEFORD, J. F.—The Santa Fé Oil Storage Plant. *Am. Mach.*, Oct. 24, 1912.

SPECIFICATIONS

ALLEN, I. C.—Specifications for the Purchase of Fuel Oil, with Directions for Sampling Oil and Natural Gas. *U. S. Bur. Min.*, *Techn. Paper* 3, 1911.

———.—The Preparation of Specifications for Petroleum Products. Bur. Mines, Washington, *Tech. Paper* 36, 1913.

DAMSKI, A. V.—On the Question of the Determination of a Standard of Quality for Burning Fuels Generally and for Petroleum Residues in Particular. *Zap. Imp. Russk. Tekhn. Obsch.*, g. xxiii, Jan., pp. 51–60; Feb., pp. 38–46, 1889.

KHATESOV, K.—Is it Desirable to Impose a Fire-test on Liquid Fuels? *Zap. Imp. Russk. Tekhn. Obsch.*, xxxi, No. 11, Trudi, pp. 105–129. 1897.

SINGER, L.—Die Lieferungsbedingungen der Regierung der Vereinigten Staaten für den Kauf vom Heizöl und Anleitungen zur Probenahme von Oel und Naturgas. *Pet. Zeitschr.*, bd. vii, pp. 153–158. 1911.

SOMMER, A.—Necessary Reforms in Specifications for Petroleum Products. *Proc. Am. Soc. Test. Mat.*, vol. x, pp. 458–471. 1910.

U. S. NAVY DEPARTMENT.—Specifications for Fuel Oil for the United States Navy. 1912.

ZALOZIECKI, R.—Eine neue Grundlage zur Festellung der Rohölpreise. *Naphta*, bd. xiv, pp. 63–67. 1906.

STOVES

ZIBOROV, M. N.—Report on the Competition of Oil Stoves and Furnaces for the War Office Prize. *Zap. Imp. Russk. Tekhn. Obsch.*, g. xxvii, March, 1893.

Domestic

BALUKEVITCH.—Domestic Oil Stoves. *Zap. Kavk. Otd. Imp. Russk. Tekhn. Obsch.*, t. xv, pt. i, 1883.

PIROTSKI, PH. A.—On Stoves—Russian and Room—and the Use in Them of Mineral Fuel. *Zap. Imp. Russk. Tekhn. Obsch.*, g. xv, otd. i, pp. 336–362, 3 pls. 1881.

TANK VESSELS

CECH, C. O.—Apparat zur vollkommen gefahrlosen Aufbewahrung (und Transportirung auf Schiffen) grossen Mengen von Petroleum, Benzin, etc. *Polyt. Journ.*, vol. cxciv, pp. 156–159. 1869.

CRAGGS, E. H.—On Vessels Constructed for the Over-sea Bulk Oil Trade. *Proc. Cleveland Inst. Eng.*, 1893, pp. 8–37.

CURRIER, D.—Oil Tank Vessels. *Marine Engineering*, vol. viii, p. 1920. 1903.

ELDRIDGE, G.—On the Weak Points in Steamers Carrying Oil in Bulk. *Trans. Inst. Naval Archt.*, vol. xxxiii, pp. 88–103, pls. v–viii, 1892.

Engineer, London.—The Diesel Oil Tank-ship "Hagen." March 21, 1913.

Engineering.—Internal Combustion Engines at the Ghent Exposition. Aug. 1, 1913.

Génie Civil.—Le petrolier à moteurs Diesel "Hagen." April 12, 1913.

GRADENWITZ, ALFRED.—A Diesel Motor Tank Vessel (carrying capacity 15,000 tons). *Marine Engng.*, Sept., 1912.

Int. Marine Engineering.—German Diesel–Engined Tank-ship "Hagen." May, 1913.

Marine Engineering.—New Tank Steamer for the Gulf Refining Company. March, 1912.

MONTGOMERIE, J.—The Arrangement and Construction of Oil Vessels. *Cassier's Mag.*, Dec., 1911.

———.—The Design and Construction of Oil Steamers. *Engng.*, Feb. 28, 1913.

———.—The Design and Construction of Oil Steamers. *Trans Inst. of Engrs. and Shipbldrs. in Scotland*, Jan. 21, 1913.

Petroleum World.—World's Record Tank Steamer. (Mexican Eagle Oil Co.) March, 1913, p. 128.

Schiffbau.—Der Petroleumtransport zur See, und die neueste Entwickelung der Tankschiffe. Serial. Dec. 11, 1912.

———.—Das Motor-tank-schiff "Hagen." March 12, 1913.

Shipbuilding.—Internal-Combustion Engines for Ocean-going Ships (tank-ship "Hagen"). May, 1913.

TOWLE, H. C.—Liquid Fuel Measurements on Oil-burning Steamships. Serial. 1st part. *Int. Mar. Engng.*, Aug., 1912.

WALKER, P. F.—Stability of an Oil-tank Steamer. *Marine Engng.*, vol. vii, pp. 492–495. 1902.

WILSON, J. RENDELL.—Twin Screw Motor-ship "Hagen." *Eng. News*, May 1, 1913.

Zap. Imp. Russk. Tekhn. Obsch.—Rules for the Transport of Petroleum in Ships and for the Use of Oil Fuel on Them. *Zap. Imp. Russk. Tekhn. Obsch.*, g. xxxvii, pp. 705–730. 1903.

Zeit. des Ver. Deutscher Ing.—Das Tankschiff "Hagen" erbaut von Fried. Krupp, A. G. Germaniawerft. April 5, 1913.

TESTING

ABEL, F. A., and REDWOOD, B.—Petroleum Testing in Tropical Climates with Abel's Apparatus. *Chem. News*, vol. xlix, p. 196. 1884.

AISINMANN, S.—Die Einheitlichen Prüfungsmethoden in der Mineralölindustrie. *Samml. Chem.-techn. Vortr.*, bd. ii, pp. 325–400. 1897.

HIGGINS, W. F.—Methods and Apparatus used in Petroleum Testing. *J'l Soc. Chem. Ind.*, June 16, 1913. *Petroleum Wld.*, June, July, 1913.

MANN, CHAS. A.—Oils and Oil Testing. *Wiscon. Engr.*, Feb., 1912.

TORPEDOES

ALLEST, J. D'.—Le Chauffage des Torpilleurs au moyen des hydrocarbures liquides. *Gén. Civ.*, t. xi, pp. 344–348, 362–363, 397–402. 1887.

CORBU, J.—Le Pétrole et les Torpilleurs. *Mon. Inst. Pétrol-Roum.*, t. x, 1909.

TRANSPORTATION

CALMEL, A.—Le Transport du Pétrole. *Journ. Ptrol.*, t. i, pp. 3–5, 21–23, 40–41, 55–56, 71–73. 1901.

NICHOL, B. G., and GRAVELL, J.—The Use and Transportation of Liquid Fuel. *Trans. N. E. Coast Inst. Eng. Shipbuilders*, vol. iii, pp. 27–51, pls. 1–11. 1887.

WASTE

Prevention of

ARNOLD, RALPH, and GARFIAS, V. R.—The Prevention of Waste of Oil and Gas from Flowing Wells in California. *Techn. Paper* 42, *Bur. Mines.* Washington, 1913.

WATER

Condition of, in Oil

WALL, M.—Some Observations on the Phenomena which take Place between Oil and Water. *Mem. Lit. Phil. Soc. Manch.*, vol. ii, pp. 435–444. 1789.

Danger of

Zts. Ver. Bohringen u. Bohrtecnik.—Die Wassergefahr in den Kalifornischen Erdölfelden (Trans. from *Pet. Review*). March 15, 1913.

Determination of

ALLEN, IRVING C., and JACOBS, W. A.—Methods for the Determination of Water in Petroleum and Its Products. *Techn. Paper* 25, *Bur. Mines.* Washington, 1912.
CURTIS, M., and TOMPKINS, P. W.—Notes on the Determination of Water in California Crude Oils. *J'l Soc. Chem. Ind.*, vol. xxi, p. 1519. 1902.

Prevention of

ARNOLD, RALPH, and GARFIAS, V. R.—The Cementing Process of Excluding Water from Oil Wells as Practised in California. *Techn. Paper* 32, *Bureau Mines.* Washington, 1913.

Removal of

ROSENTHAL, T.—Die Entwasserung von rohem Erdöl. *Pet. Zeitschr.*, bd. v, pp. 315–316. 1909.

Books

A History of Fossil Fuel London, 1841.
ABEL, F. A.—Report to the Secretary of State for the Home Department on the Subject of the Testing of Petroleum. Fo., London, 1876.
AISINMANN, S.—Taschenbuch für die Mineralölindustrie. Berlin, 1896.
ALLEN, A. H.—Commercial Organic Analysis. 4 vols. London, 1879, 1882.
ALLEN, H.—Modern Power Gas Producer Practice and Applications. London, 1908.
ALIMANESTIANU, H. C.—Question de la concession des terrains pétrolefères situés sur les propriétés de l'état et des conduites pour le transport du pétrole en Roumanie. Bucharest, 1900.
ANSTRY, H. C.—Liquid Fuel. A new chapter in Ed. II of English translation of Chaudières Marines (L. E. Bertin). London, 1906.
ARENDS, H., and MOSSNER, C.—Handbuch für die internationale Petroleumindustrie. Berlin, 1911.
BALE, M. P.—Gas and Oil Engine Management. London, 1904.
BELL, A. M.—Petroleum Oil Fuel. London, 1902.
BERTHELOT, M. P. E.—Les Carbures d'Hydrogene, 1851–1901. Recherches experimentales. 3 Tt. Paris, 1901.
BERTIN, F.—Chaudières Marines. Paris, 1896. (There is also an English translation. London, 1896.)
BIENAYME, A. F. H.—Les Maschines Marines. Paris, 1877.
BISCHOF, C. G. C.—Lehrbuch der chemischen und physikalischen Geologie. 2 Bde. Bonn, 1847, 1854.
BJORLING, P. R.—Briquettes and Patent Fuel. London, 1903.
BLOOMER, A. P.—Petroleum Fuel. St. Petersburg, 1888.
BODDE, D.—An Essay to show that Petroleum may be used with Advantage in Manufacturing Operations, for the Purpose of Heating Steam Boilers and Generating Steam. The Hague, 1865.
BOLLES, A. S.—Industrial History of the United States. Norwich, Conn., 1879.
BONE, J. H. A.—Petroleum and Petroleum Wells. Philadelphia, 1865.
BOOTH, W. H.—Liquid Fuel and its Combustion. London, 1903.

W. H. Booth.—Liquid Fuel and its Applications. London, 1912.
Bowen, E.—Coal and Coal Oil. Philadelphia, 1865.
Boyd, R. N.—Petroleum; its Development and Uses. London, 1895.
Brannt, W. T.—Petroleum: Its History, Origin, etc. Philadelphia and London, 1895.
Brewer, R. W. A.—Carburation in Theory and Practice. 1913.
Brislee, F. J.—An Introduction to the Study of Fuels. New York, 1912.
Buchenau, F.—Ueber Petroleum. Berlin, 1872.
Burat, A.—Traité du Gisement et de la Recherche des Mineraux Utiles. Paris, 1870.
Burns, W.—Illuminating and Heating Gas. A Manual of the Manufacture of Gas from Tar, Oil, and other Liquid Hydrocarbons, and Extracting Oil from Sewage Sludge. London, 1887.
Butler, E.—Carburettors, Vaporisers and Distributing Valves Used in Internal Combustion Engines. London, 1909.
Cameron, James.—Oils and Varnishes. London, 1868.
Carpenter, R. C., and Diederichs, H.—Internal Combustion Engines. London, 1908.
Chalkley, A. P.—Diesel Engines for Land and Marine Work. 1913.
Clark, A. G.—Text-book on Motor Car Engineering. 1913.
Clavenad, C.—Notice sur les Chaudières marines au goudron liquide de pétrole. Paris, 1894.
Clerk, D.—The Gas Engine. London, 1886.
———.—The Gas and Oil Engine. London and New York, 1896.
———.—The Gas, Petrol and Oil Engine. New York, 1910.
Cogniet, C.—Les huiles minérales au point de vue de leur emploi pour le chauffage des machines à vapeur. Paris, 1868.
Colomer, F., and Lordier, C.—Combustibles Industrielles, Houille, Pétrole, Lignite, Tourbe, Bois, Charbon du Bois, Agglomérés, Coke. Paris, 1903.
The Derrick's Hand-book of Petroleum, 1859–1898. Oil City, Pa. 1898.
Deutsch, H.—Le Pétrole et ses Applications. Paris, 1894.
Donkin, Bryan.—Gas, Oil and Air Engines. London, 1896.
Engler, C., and Höfer, H.—Das Erdöl, seine Physik, Chemie., etc. Leipzig, 1909.
Gulischambarov, S. I.—Die Naphthaheizung der Dampfer und Locomotiven. St. Petersburg, 1880
———.—Essai d'une Bibliographie générale de l'Industrie des Pétroles. St. Petersburg, 1883, 1884.
———.—Petroleum Heating of Steamships, Locomotives, Stationary Boilers, Etc. St. Petersburg, 1894.
———.—The Use of Petroleum for Domestic Purposes, Kitchens, Etc. St. Petersburg, 1887.
———.—The Use of Petroleum for Metallurgical Purposes. 1888.
Hefter, Gustav.—Technologie der Fette und Oele. Berlin, 1910.
Henry, J. D.—Oil Fuel and the (British) Empire. London, 1908.
Hicks, J. A.—The Laboratory Book of Mineral Oil Testing. London.
Hodgetts, E. A. R.—Liquid Fuels for Mechanical and Industrial Purposes. London, 1890.
Höfer, H.—Die Petroleum-Industrie Nord-Amerikas. 1877. Wien-Bericht ueber die Weltausstellung in Philadelphia. 1876.
———.—Das Erdöl und seine Verwandten. Brunswick, 1888.
Humboldt, A.—Fuel. London, 1897.
Immenkötter, T.—Ueber Heizwertbestimmungen mit besonderer Berücksichtigung gasförmigen und flüssiger Brennstoffe. Berlin, 1905.
Inchley, William.—The Theory of Heat Engines. 1913.
Ivanov, N.—Fuels. Memorandum-book for Miners and Engineers. 1863.
Khelimski, G. G.—New System of Oil Heating with Preliminary Heating of the Oil. Tiflis, 1899.
Kirschke, A.—Gas and Oil Engines. Trans. by Chas. Salter, 1913.
Kissling, R.—Das Erdöl, seine Verarbeitung und Verwendung. Monogr. Chem.-techn. Fabrik-Methoden, bd. xii. 1908.
Klitzsch, G.—Ueber das Vorkommen, die Eigenschaften und die Enstehung des Petroleum. 1887.
Krüger, R.—Die Lehre von den Brennmaterialien. Jena, 1883.
Lew, I.—Die Feuerungen mit flüssigen Brennmaterialien. Stuttgart, 1890.
Lewes, V. B.—Liquid and Gaseous Fuels and the Part they Play in Modern Power Production. London, 1907.

LEWKOWITSCH, J.—Chemical Technology and Analysis of Oils and Waxes. London, 1904
LIECKFELD, G.—Oil Motors.
MATHOT, R. E.—The Construction and Working of the Internal Combustion Engine. Translation by W. A. Tookey, from the French. New York, 1910.
MILLS AND ROWAN.—Groves and Thorpe's Chemical Technology. Vol. i, Fuels Philadelphia, 1889.
MIRON, F.—Les Huiles Minérales. Paris, 1897.
MITZAKIS, J.—The Russian Oil Fields and Petroleum Industry. London, 1911.
MOLINARI, F.—Combustibili industrialli e petrolio. Milan, 1892.
MUNK, E.—Ueber Rohölfeuerungen. Vienna, 1910.
NIKITINSKI, YA.—Petroleum and its Products. Moscow, 1880.
NORTH, S. H.—Petroleum: Its Power and Uses. London, 1904.
———.—Oil Fuel: Its Supply, Composition and Application. London, 1905. 2nd Ed. by Edward Butler, 1911.
OLEARIUS, A.—Voyages and Travels of the Ambassadors sent by Frederick, Duke of Holstein, to the Great Duke of Moscovy and the King of Persia. 1647, 1656, 1669. Fo., London, 1662.
PAINE AND STROND.—Oil Production Methods.
PECKHAM, S. F.—The Production, Technology and Uses of Petroleum. Washington, 1874.
PERCY, JOHN.—Metallurgy: Fuel. London, 1875.
PHILLIPS, H. J.—Fuels: Their Analysis and Valuation. London, 1892.
PLATONOV, K S.—Materials for the Study of Existing Conditions of Decrease and Consumption of Petroleum Products abroad and in Russia. Baku, 1903.
POOLE, H.—The Calorific Power of Fuels. New York, 1907.
RAGOZIN, V I., MARKOVNIKOV, V., and OGLOBIN, V. N.—Petroleum and the Petroleum Industry. St. Petersburg, 1884.
RAMSAUER, P.—Petroleum. Oldenburg, 1886.
REDWOOD, B.—Petroleum and its Products. 2nd Ed., London, 1906.
———.—A Treatise on Petroleum. 3rd Ed., 3 vols., London, 1913.
ROSSMÄSSLER, F. A.—Die flüssigen Heizmaterialien und ihre Anwendung. Vienna, 1910.
SNIDER, L. C.—Petroleum and Natural Gas in Oklahoma. Oklahoma City, Oklahoma, 1913.
SOULIÉ, E. and HAUDOUIN, H.—Le Pétrole. Ses gisements, son exploitation, etc. Paris, 1865.
STILLMAN, T. B.—Engineering Chemistry. Easton, Pa., and London. 4th Ed., 1910.
STRICKLAND, F.—Petrol Motors and Motor Cars.
TASSART, L. C.—Exploitation du Pétrole. Paris, 1908.
TATE, N.—Petroleum and its Products. London, 1863.
TELECZINSKI, A.—Petroleum and its Use as Commercial and Domestic Fuel. Lemberg, 1870.
THOMPSON, BEEBY.—Petroleum Mining. London, 1910.
THOMPSON, J. H., and REDWOOD, B.—Handbook on Petroleum. London, 1901.
THORPE, EDWARD.—Dictionary of Applied Chemistry. 5 vols., 1913. London and New York.
THWAITE, B. H.—Liquid Fuel. London, 1887.
TOOKEY, W. A.—Oil Engines. London, 1904.
TOWER.—The Story of Oil. New York, 1909.
TUMSKI, K. I.—Oil and its Products. Moscow, 1879.
VEITH, A.—Das Erdöl und seine Verarbeitung. Brunswick, 1892.
VERSENEV, V.—Manual of Management of Petroleum Fired Boilers. Moscow, 1891.
VOSNESENSKI.—Petroleum Firing. Kiev, 1882.
WALTER, E.—Die entleuchtete Heizbrenner für Gase und flüssige Brennstoffe. Halle a S., 1909.
WELLS, G. JAMES, and WALLIS-TAYLER, A. J.—The Diesel or Slow Combustion Oil Engine, 1913.
WHITE, A. H.—Technical Gas and Fuel Analysis. New York and London, 1913.
WHITE, I. C.—The Waste of our Fuel Resources. (Conference on Conservation of Natural Resources). Morgantown, 1908.
WILKIE.—Petrolia, or the Oil Regions of the United States. Chicago, 1865.
WILLIAMS, C. W.—Fuel: Its Combustion and Economy. London, 1879.
WIMPERIS, H. E.—The Internal Combustion Engine. London, 1908.
———.—Primer of the Internal Combustion Engine.
WISCHIN, R. A.—Vademecum des Mineralöl Chemikers. Brunswick, 1896.
WRIGHT and BUTLER, LTD.—Petroleum. Birmingham, England, 1887.

The Russian Oil Fields

BY A. ADIASSEVICH, ST. PETERSBURG, RUSSIA

(New York Meeting, February, 1914)

PETROLEUM has been found in Russia in various localities from north to south, as may be seen from the list given below:

(a) In the basin of the Petchora river, Northern Russia.
(b) In the basin of the Volga river, in the governments of Samara and Saratoff.
(c) In the government of Astrakhan and in the Uralsk territory, close to the northern and eastern coast of the Caspian sea.
(d) At Grozny in Northeastern Caucasus.
(e) In the Daghestan territory, Eastern Caucasus, on the Caspian sea.
(f) On the Apsheron peninsula (Baku and other districts) close to the Caspian sea shore.
(g) On the island of Tcheleken in the Caspian sea, also on the island of Sviatoi.
(h) In the Transcaspian territory on the Neftianaia Gora (Oil hill) and on the surrounding hills.
(i) In the Ferghana valley in Russian Central Asia.
(j) On the Kertch and Taman peninsulas on the Black sea.
(k) In Siberia it has been discovered in the Transbaikal territory and on the island of Sakhalin.

In the above-mentioned districts petroleum has been found to exist under different geological conditions and to vary in its chemical and physical properties.

At the present time petroleum is produced in Russia at Baku, Grozny, on the island of Tcheleken, in the Ferghana district, and in the Uralsk territory. The yearly production in 1912 throughout the Russian Empire amounted to 69,400,000 barrels, of which the Baku fields were responsible for 52,000,000 barrels. This shows that the Baku fields on the Apsheron peninsula are the chief oil-producing centers in Russia, being at the same time the oldest of all our oil fields. In this paper I shall discuss the Baku fields only, leaving all the others until a later date.

The Apsheron peninsula in the Eastern Caucasus protrudes into the Caspian sea in the shape of a triangle some 47 miles long covering a total area of some 750 square miles. The eastern part of the peninsula is a flat, slightly rolling plain, rising in its highest parts to 140 to 170 ft. above

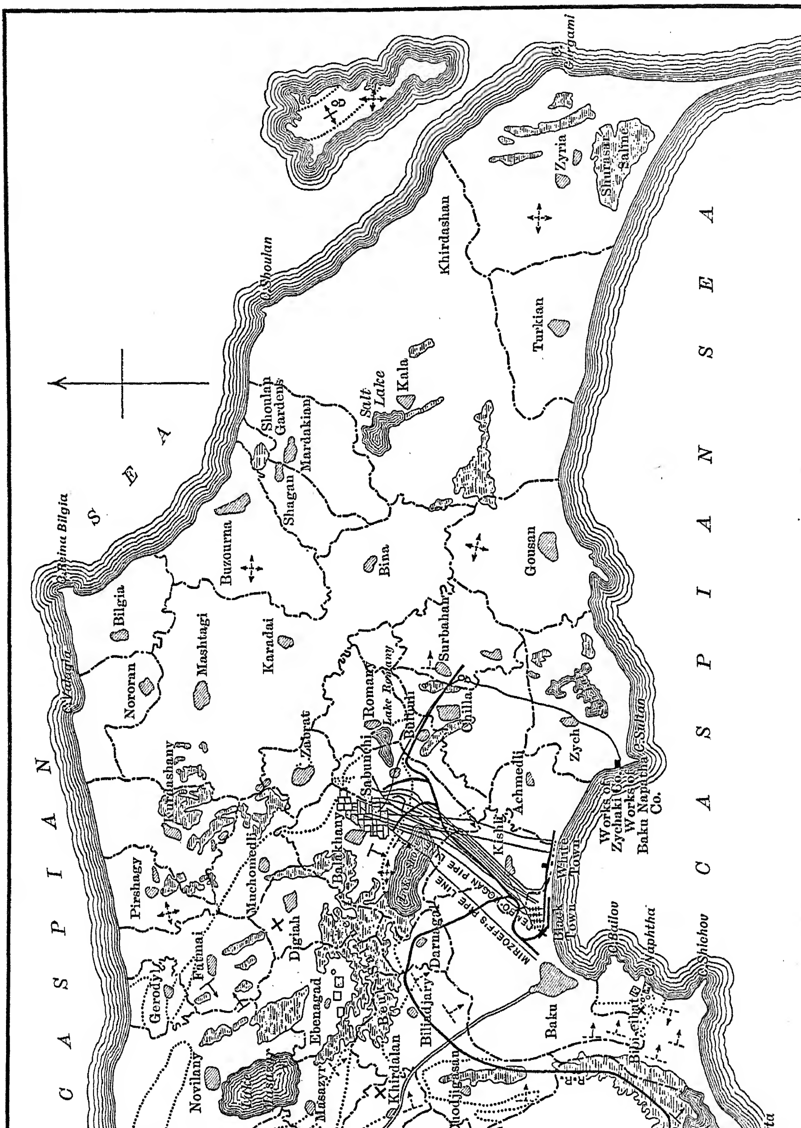

FIG. 1.—MAP SHOWING THE RUSSIAN OIL FIELDS.

the level of the Caspian sea. The monotony of the country is relieved by rows of low hills or limestone ridges; on the clayey and sandy surface occur shelly limestone terraces. In the western part are scattered over the rising country elevated plateaus divided by deep ravines; separate ranges of rugged hills make their appearance and their summits rise to 840 to 1,200 ft. (Shaban-dag). In the lowlands accumulations of brine water form regular lakes; these shallow lakes dry up during the hot season

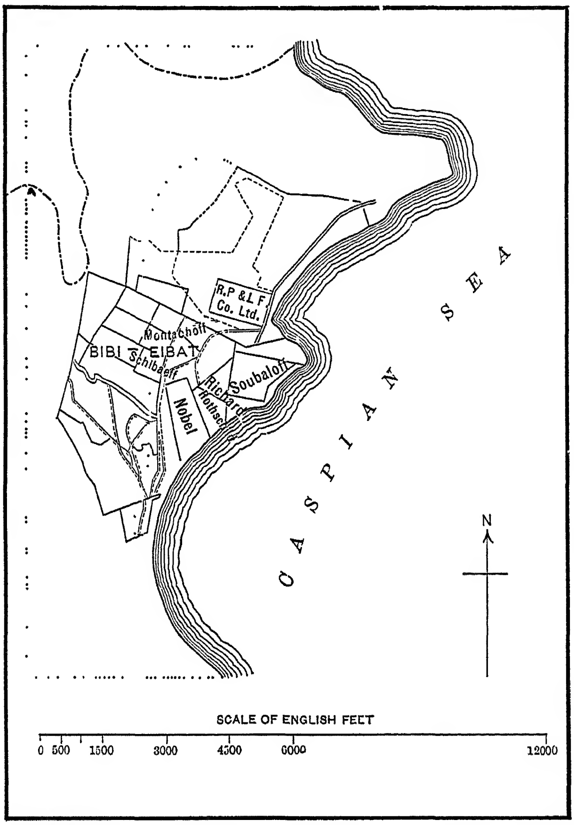

FIG. 2.—THE BIBI-EIBAT OIL FIELD.

leaving numerous salt marshes. The peninsula has the aspect of a sandy desert owing to lack of fresh water and partly also to sandy soil. In early spring, after the winter rain, the country is covered with low grass and bright flowers; even some meager crops are raised at the time; but by the end of May all vegetation is burned by the scorching rays of the southern sun. However, on the northern coast of the peninsula, where fresh water is more plentiful, there are cultivated fields, vineyards, and orchards.

The sedimentary rocks composing the Apsheron peninsula belong to the post-Tertiary and Tertiary periods.

The post-Tertiary is composed of loess, loam, blown sands, gravel formations, and silt, which spread throughout the peninsula. The marine deposits are Caspian terraces of friable shelly limestone, conglomerate, and gravel. These sedimentary deposits, some 140 ft. thick, are horizontal and lie unconformably on the underlying beds.

The Tertiary is represented by:

Pliocene deposits:

(*a*) The Baku series, consisting of limestones, sands, clays, and conglomerates, deposited unconformably on the lower series. The series contains the following fossils: Cardius crassum Baeri; Adacna plicata; Adacna edentula; Adacna vitrea; Monodacna caspia; Dreissensia Tschandæ Andr.; Dreissensia bugensis Andr.; Dreissensia polymorpha; Neretina luturata; Clessinia variabilis; Micromelania.

(*b*) The Apsheron series, consisting of limestones, oölitic limestones, marls, sands, sandstones, dark-colored clays with thin interlayers of volcanic ash and sand and deeper dark clays with interlayers of sands and black clays; among these strata are occasionally met hard sandstones and boulders. The following fossils are characteristic of these series: Apsheronia propinqua; Apsheronia Euridesma Andr.; Apsheronia raricosta Andr.; Didacna intermedia; Monodacna nitida; Monodacna Sjogreni; Monodacna trapezinum; Dreissensia anisoconcha; Dreissensia rostriformis; Dreissensia latro; Limnæa obtusa; Cypris.

The Pliocene is some 1,225 ft. thick.

Miocene deposits:

Black clays underlain by marls, light and dark clays with interlayers of volcanic sand, sands, sandstones, and limestones. These deposits are characterized by the following fossils: Mactra carabugasica Andr.; Mactra subcaspia; Cardium Vog. Andr.; Cardium dombra Andr.; Cardium eduleformis; Potamides caspius; fishes.

The formations are classified by Professor Andrussoff as belonging to the Akchagil series, their thickness being from 125 to 175 ft.

Under these series lie thick gray, blue, and brown clays, sometimes with sand, also thick marls interstratified with sands. The upper part of these deposits contains marine and lacustrine fauna (Limnæus armanensis Naulet., Planorbis cornu, P. costatus, Glandina, Succinea, Paracypris, the plant Chara), while in the lower part no fossils have ever been found. This is the oil measure, some 5,600 ft. thick.

This latter is underlain by sandy clays and at the bottom by char-

acteristic striated clays, in their turn underlain by layers of siliceous limestone containing numerous fossils of spirialis species, also Lucina, the fish Leptolepis and scales of Meletta crenata. Farther down follow shaly sandy clays with remnants of Cedroxylon, ferruginous sands, and dark chocolate clays containing fish remains (Amphisyle, Lepidopus, scales of Meletta). Then at last are found shaly clays belonging to the lower Tertiary, probably to the Oligocene.

This completes the succession of rocks comprising the Apsheron peninsula, as far as could be ascertained up to now by means of boring logs, samples of rock from drilled wells, natural outcrops, and the prospecting work carried on by the Geological Committee.

Both the Pliocene and Miocene strata are dislocated, leading to the formation of anticlinal and synclinal folds and dome-shaped uplifts, disturbed in their turn by a number of thrusts and faults in various directions.

The general trend of all uplifts on the peninsula corresponds to the direction of the main Caucasian ridge from northwest to southeast. But besides this upheaval there are others in various directions—viz., one in a west-east direction and another from northeast to southwest. These uplifts in various directions make the geotechtonic of the peninsula very complicated.

As an example of typical uplifts in the shape of an elongated dome we can cite the Kirmaku-Balakhany-Sabunchy-Ramany and also the Bibi-Eibat folds. To the south of Ramany we meet the Surahkany fold and at a distance of 1 mile to the north of Bibi-Eibat lies the Atashka-Shabana anticlinal, of a north-south direction. Farther westward we notice a fold beginning from Mount Lock Botan and stretching beyond Mounts Kergez and Kizkala, where outcrop to the surface the strata composing the southern and western wings of this anticlinal. In the northern part of the peninsula are also to be found several distinct folds.

Following the line of main uplift, we notice a series of mud volcanoes, many of which, even at the present time, spout mud and water, gases, and petroleum. The natural oil issues scattered throughout the peninsula, mainly in its central and western parts, occur in the places which have been mostly subjected to the influence of the disturbing forces. Oil has been observed to emanate from layers of all the above described series from the Akchagal to the lower green clays. However, in commercial quantities oil is found only in several localities and its accumulations are dependent on some specially favorable geological conditions, such as are presented in this locality by the dome-shaped folds of the Balakhany-Sabunchy-Ramany and Bibi-Eibat fields.

The presence of petroleum on the Apsheron peninsula around Baku was known from very olden times and the local Persian population, before and after the Russians came to the country, used to dig shallow

wells or produce the oil from natural seepages, mostly near the village Balakhany, where the oil-bearing strata (since extensively worked) rise very close to the surface. In an eastern direction near the village of Surakhany the natural gas used to escape so abundantly from the fissures of the earth that a fire-worshipers' temple was erected on the spot, where the gas burned night and day in lofty flaring torches, and pilgrims flocked to the temple from Persia and even from distant India.

The first borings were started in 1870, in the central part of what was later known as the Balakhany fields, close to the hand-dug tests, and the first big gushers were obtained from depths averaging 120 to 350 ft., the oil spouting at the rate of some 30,000 barrels per day. After the first successful gushers were brought in the boring operations extended eastward and soon spread over the lands of the adjoining Persian villages of Sabunchy and Ramany, all three lying at a distance of some 10 miles inland in a northwest direction from Baku city (and port on the Caspian sea). These three fields have since borne the names of the three villages, although they have long since merged into one continuous field covering some 1978 acres. This is the territory from which comes the main part of the Russian oil. In an eastern direction from these lies the Surakhany field, which ever since the fire-worshipers' days was recognized as a very good gas producer, but where later vast amounts of light oil have been discovered and a good many big gushers were brought in.

Close to Baku city in an eastern direction, on the very shore of the Caspian, lies another small but very productive field—the so-called Bibi-Eibat field. Production was started here in 1880.

The Balakhany-Sabunchy-Ramany fields, and the Kirmaku field adjoining Balakhany on the west, which although worked up to the present only by hand-dug wells on the outcrops must be discussed as a whole with the others, are situated in the central section of the eastern end of the Apsheron peninsula on a slightly undulating tableland stretching from northwest to southeast. The country slopes here from northwest to southeast toward the former Ramany lake (salt). The central part seems to be slightly uplifted. The fields as a whole are surrounded by limestone ridges from north, east, and south, rising from 70 to 140 ft. above the surrounding country. The highest points within the fields territory are the mud volcano Bog-Boga (287 ft.) and the Kirmaku range, with a summit of the same name (330 ft.). This range follows a north-south direction. The strata dip here from west to east at an angle of 70°, forming an anticlinal, in the central part of which outcrop to the surface the lower series of the oil measure, composed of siliceous limestone and comprising spirialis specia. These siliceous formations are overlain by thick oil-bearing sands with thin interlayers of clays and sandstone of a total thickness of 900 ft. In its southern part the Kirmaku anticlinal bends eastward toward the Balakhany-Sabunchy-Ramany fields. On

these latter fields the strata composing the oil measure form a wide quaquaversal anticlinal, the strata dipping north, northeast, east, southeast, and south. In the central part of the oil fields the upper layers have been washed off and therefore the natural denudations or artificial shafts and shallow trenches reveal to our eyes all the consequent strata, beginning from Mount Kirmaku, in an eastern, northern, and southern direction.

The thick oil-bearing sands, which are outcropping near Mount Kirmaku, are the lowest pay sands in this part of the oil fields and these sands are worked on the slopes of the mountain by the local Persian villagers by means of shallow hand-dug wells. These sands are covered by some 100 ft. of clays, overlain in their turn by some 300 ft. of sands and sandstone comprising thin streaks of pay sands. On the top lie again clays about 200 ft. thick. These are followed by thick water-bearing sand and sandstone over 700 ft. thick and again some 400 ft. of clays, sand, and sandstone. Farther eastward, a series of oil sands interstratified with clays and barren sands outcrop to the surface, the total thickness being some 600 ft.; here we find as many as 15 separate and distinct pay-sand layers. These sands are worked on the outcrops by the villagers by means of shallow hand-dug wells. Still farther eastward sands interstratified with sandstone outcrop; this water-bearing formation is 700 ft. thick. This thickness is overlain by a series of pay sands with clay interlayers, barren sands, water-bearing sands, and sandstones, of a total thickness of 1,300 ft.; here we find some 22 separate pay-sand layers. Over it we meet a series of clays and sands barren of oil, of a total thickness of some 600 ft., and above the characteristic Akchagil layers, composed of dark clays with interlayers of volcanic ash and of marls. The Akchagil is overlain by clays, marls, sands, sandstones, and limestones belonging to the Apsheron. The middle Apsheron limestones, as was stated above, surround the producing fields, but are washed off in the central part. The Akchagil series rise to the surface from under the Apsheron layers in the northern part of the fields, turn southward, and are sporadically met with in the southern section of the fields. The clays and sands overlying the pay-sand beds thin out westward and within the limits of the Balakhany field disappear altogether, and the upper oil sands are met here quite close to the surface.

It is evident from the above description that within the boundaries of the Balakhany-Sabunchy-Ramany oil fields we have three divisions of oil-bearing sands; the first and topmost having a thickness of some 1,225 ft. together with the interlying clays, while the thickness of the pay sands alone reaches some 600 ft., whereas separate pay-sand beds vary from several feet to 70 ft. This first division, as shown above, is divided from the second by thick water-bearing sands and sandstones. The second oil division out of a total thickness of some 600 ft. comprises

280 ft. of oil sands, and at last we come to the lowest and thickest Kirmaku oil division, which contains hardly any barren interlayers at all.

Of these three oil divisions only the first has been extensively worked, and all the oil which has been obtained from these fields during the 40 years since the first boring wells were sunk here has been produced from these 600 ft. of oil sand. As stated before, the first gushers on the Balakhany field were brought in from a depth of 120 to 350 ft. At the present time the average depth of producing wells at Balakhany is over 900 ft. (minimum, 300 ft.; maximum, 1,800 ft.) and the production has been reduced from gushers to an average of 8,000 barrels per well per year, or some 25 barrels per day.

On the Sabunchy field the average depth of producing wells at the present time is about 1,200 ft. We know from the description and the sketch given above that the oil-bearing layers on this field are to be found under a greater thickness of overlying barren beds, and the depth of wells varies from about 700 to 2,300 ft. We shall further see that on the Ramany field, which lies still further along the dip of the strata, the wells have to go down to still greater depths. The production on the Sabunchy field averages 55 barrels per well per day, or some 17,000 barrels per year. A considerable drop of production has been noticed here during the last few years; 10 years ago the average production stood at 45,000 barrels per well per year.

On the Ramany field the average depth of producing wells is 1,600 ft. (minimum, 1,000; maximum, 2,450 ft.). The average production per well per day is 110 barrels, or per year some 26,500 barrels, whereas some 10 years ago the yearly production per well was 80,000 barrels.

Below I give a short summary of the Baku production, also the number of producing wells, average production per well, and the number of gushers. In these statistics I include the Bibi-Eibat field, which will be discussed on the following pages:

Besides the above mentioned number of producing wells in 1913, about 500 wells were being drilled on all the four fields, about 400 wells were being deepened to the next producing stratum, and in about 1,800 wells work had been temporarily stopped. This brings the number of wells on all four fields to 5,590.

All this enormous amount, 1,113,700,000 barrels of oil on the three fields, Balakhany-Sabunchy-Ramany, has been drained from the 600 ft. thick sands of the first oil division. The second oil division has been only lately reached by a few wells on the Balakhany fields, but these wells have only served as tests and no oil has been extracted from those still virgin beds; the wells will have to reach a depth of 3,500 ft. and deeper. After this division is exhausted we have still the deepest, or Kirmaku, oil division. Thus we see that, although the production of oil from the first oil division threatens to drop from year to year, we

Baku Statistics

Years	Balakhany		Sabunchy		Ramany		Bibi-Eibat		Total		Production Per Well	Number of Gushers	Spouted Oil Per Cent.
	Wells	Production Barrels	Wells	Production Barrels	Wells	Production Barrels	Wells	Production Barrels	Wells	Production Barrels			
1899	610	14,350,000	543	28,840,000	138	12,350,000	58	10,100,000	1,349	65,640,000	48,500	23	15.3
1900	736	15,600,000	665	31,450,000	185	14,350,000	112	13,630,000	1,698	75,030,000	44,000	25	11.3
1901	775	14,700,000	780	36,920,000	213	15,520,000	143	16,690,000	1,911	83,830,000	43,500	35	14.6
1902	720	12,680,000	751	33,390,000	219	17,490,000	135	15,930,000	1,825	79,490,000	43,000	42	14.9
1903	693	11,080,000	747	28,800,000	221	14,990,000	174	19,690,000	1,835	74,560,000	40,000	33	8.9
1904	732	10,250,000	791	27,260,000	253	16,680,000	222	22,640,000	1,998	76,830,000	38,000	26	5.8
1905	750	7,040,000	730	17,400,000	245	10,900,000	248	15,830,000	1,973	51,170,000	25,000	26	3.3
1906	739	8,500,000	712	19,600,000	253	11,920,000	250	15,950,000	1,954	55,970,000	28,000	20	2.4
1907	836	8,910,000	873	23,000,000	278	11,200,000	305	16,400,000	2,292	59,510,000	26,000	28	2.5
1908	879	8,790,000	981	24,860,000	279	9,780,000	356	14,950,000	2,495	58,380,000	23,400	18	2.0
1909	917	9,110,000	1,059	25,880,000	285	10,960,000	371	15,350,000	2,632	61,300,000	23,300	19	4.2
1910	962	8,530,000	1,177	24,390,000	305	12,010,000	396	14,860,000	2,840	59,790,000	21,000	19	3.2
1911	937	7,860,000	1,235	22,000,000	330	10,350,000	390	12,810,000	2,892	53,020,000	18,300	13	2.4
1912	1,008	8,160,000	1,358	21,300,000	373	9,850,000	403	13,070,000	3,142	52,380,000	16,700	....	3.1

The total production of the Balakhany-Sabunchy-Ramany fields since the beginning of their exploitation amounts to:

	Barrels
Balakhany field, area 857.5 acres, since 1870	279,100,000
Sabunchy field, area 877.5 acres, since 1878	594,100,000
Ramany field, area 243.0 acres, since 1890	240,500,000
Total 1,978 acres	1,113,700,000

The total production of the Bibi-Eibat field, area 520 acres, since 1880 268,500,000

have at Baku some deeper oil horizons which are practically virgin ground. We shall further see that on the Bibi-Eibat field there are also unexhausted deeper horizons, while all around Baku on the coast of the Caspian and further inland prospecting work reveals new oil-bearing territories.

The Bibi-Eibat field lies in a valley of the same name stretching from Cape Bailoff to Cape Shikhoff at a distance of a couple of miles from Baku city. The valley extends in a narrow belt for a mile along the sea coast; on the north and west it is bordered by lofty cliffs in the shape of a horseshoe. The width of the section under actual exploitation is about 5,000 ft., its area being about 520 acres, out of the 800 acres comprised in the valley limits. The general incline of the valley is from northeast to southwest.

The rocks forming the Bibi-Eibat valley, as elsewhere on the Apsheron peninsula, belong to the post-Tertiary and Tertiary formations. The surrounding cliffs are shelly limestone, marl, clay, sandstone, and sand of the Apsheron series.

On the surface we find horizontal sheets of recent Caspian sediments overlying the lower beds of the Apsheron series. These latter reach in different parts of the valley a thickness of 500 ft. They outcrop in the central part, where they are washed off to a certain extent. The Apsheron is underlain by the Akchagil, of a total thickness of some 175 ft.; this is supposed to stratify unconformably with the overlying Apsheron beds. The Akchagil is underlain by a number of interstratified sands, sandy clays, clays, and marls, composing the oil measure, which has been exhaustively prospected and worked by numerous wells to a depth of 2,500 ft., while several wells have gone below 2,800 ft. Most of the sand layers are saturated with oil and gas, the distinguishing feature being that on the Bibi-Eibat field the series overlying the oil measure and even the Akchagil beds, which are always barren on the other group of fields, are mostly impregnated with oil.

Down to a depth of about 2,900 ft. we meet over 30 separate oil-bearing sand layers, from 7 to 90 ft. thick, with a total thickness of about 600 ft. In the upper horizons the pay sands are divided by impervious clay interlayers. The number and thickness of these clay layers decrease with the depth and the oil horizons are isolated in a far inferior way from the circulating water. Below the 2,900 ft. prospecting has revealed the presence of a number of oil-bearing sand strata. They outcrop in the Jassamal valley about 1 mile west of Bibi-Eibat and are actually worked by shallow hand-dug wells on the slopes of Mount Shaban-dag.

Long observations have established the fact that at Bibi-Eibat in its eastern part the strata dip north-northeast, east, and southeast, and in the western part, southwest and south-southwest. This indicates that

these strata had been uplifted into an elongated dome with its axis running in a north-northwest and south-southeast direction. The angle of dip is 7° to 22°. The strata are further fractured by faults chiefly of a northwest-southeast direction, but also running from northeast to southwest. The origin of these faults is the subject of some controversy. Some authorities maintain that the formation of the fold is due to the plicative forces; *i.e.*, that the strata were uplifted into a dome-shaped anticlinal and the faults are of subsequent formation, especially as they do not reach any considerable depth. Other geologists are of opinion that the Bibi-Eibat uplift is the result of upward faulting (horsts) which played a prominent part in the formation of the field, and the oil deposits of the valley, as well as the productiveness of the various sections, depend on the presence of such faults.

As stated before, the Bibi-Eibat field has been worked since 1880 and 268,500,000 barrels of oil have been drained from that field. The average depth of wells on this field at the present time is over 2,000 ft. (minimum, 1,400; maximum, 2,900 ft.), while the production per well per day averages 110 barrels or per year about 33,000 barrels, having dropped during the last 10 years from 118,000 barrels.

On the Bibi-Eibat field some of the wells show up to now a considerable gas pressure, and in sinking wells to horizons exceeding 2,000 ft. big gushers are frequently brought in. We have reason to believe that the deeper strata, below 2,900 ft., contain virgin oil reserves.

As far as the petrography of the oil fields of the Baku district is concerned, it was found that the clays overlying the producing series as well as those interstratified with the sand layers are of various colors—black, gray, blue, different shades of brown; they merge into one another and in neighboring wells differently colored clays are found at corresponding depths. The clays are pure or with an admixture of sand. Sometimes gravel or boulders are imbedded in clays. Generally the clays contain salt and lime.

It has been observed that at Bibi-Eibat as well as on the Balakhany-Sabunchy-Ramany fields beds of clay occur extensively in the upper horizons and often reach a considerable thickness, while in the lower horizons sands predominate.

The clay layers play an important part at the oil fields, as they are the impervious partitions between the oil-bearing and water-bearing layers and the water is usually shut off in these clay beds.

The sand layers interstratified with clays are recorded in boring logs at Baku as water, gas, or oil bearing sands. The first is usually grit which is frequently water bearing. The second is a fine sand with a large admixture of clay. The third, or oil sand, is a fine-grained sand impregnated with oil. If such a sand is barren of oil it is recorded as oil sand or washed oil sand.

Oil sands from some of the wells were subjected to analysis and it was found that all of them contain quartz and mica and most contain carbonate of lime. Traces of copper and iron pyrites were discovered in some. In one case a feldspathic mineral was observed, in another rutile, in a third case a single crystal with the character of beryl.

Reference has been made above to the water-bearing sands and sandstones, dividing the first and second oil divisions. But unfortunately this is not the only water horizon at the Baku fields. Water-bearing layers are met throughout the thickness of strata, but mostly in the lower producing horizons. As a rule, especially in the lower horizons, all barren sands, or those from which oil was drained, are saturated with water, which seems to take the place of oil in such sands. These water-bearing sands are usually incased between beds of clay and should thus be well isolated, except for the numerous faults, which cut through the fields in all directions and serve as a connection between the water and oil sand layers.

On the Balakhany-Sabunchy-Ramany fields water-bearing sands occur, beginning from a very shallow depth of some 70 to 100 ft. and continuing throughout the whole of the first division, while at Bibi-Eibat down to 1,400 ft. there are no well-defined water layers; abundant water outflows occur in lower horizons, especially at 2,100 and 2,650 ft.

The water-bearing sands vary not only in different parts of the fields, but even on the same plot and in the same well, in consequence of varying admixture of clay, the proximity of faults, the character of the overlying and underlying strata, etc.

The waters circulating in the strata of the Baku oil fields may be subdivided into surface waters and deep-layer waters, which in their turn may be subdivided into the waters of upper and lower horizons. All the waters are saline, with varied contents of solid matter. The surface waters usually contain little mineral matter.

The waters circulating in the producing strata are more saline than the surface waters and differ from them in the chemical composition of the solid matter. On the whole, the waters are less saline in the upper horizons, the contents of salt increase with depth, and then again rise less saline waters, which often serve as an indication of the rise of deep water into upper horizons. At Bibi-Eibat to a depth of 2,500 ft. the waters vary from 11° to 9° Bé., while below the density drops to 7.5° and 6° Bé. All the waters analyzed contain alkalies (potassium, sodium, magnesium, and calcium) and also chlorine and carbonic acid. No sulphuric acid has been discovered in the waters from the wells of the Balakhany-Sabunchy-Ramany fields, whereas over 50 per cent. of the Bibi-Eibat waters analyzed contained traces or larger amounts of sulphuric acid.

These and similar observations are of the highest practical importance,

as very often they serve as guides in tracing the origin of the water which floods the wells in one or another part of the fields. Among other very important identifying data we must mention the temperature at the bottom of the various wells. On the Balakhany-Sabunchy-Ramany field such temperature varies between 19.8° and 43.4° C. and on the Bibi-Eibat fields between 34.2° and 52.2° C.

Statistics indicate that the oil-bearing strata which are being worked at the present day on the Balakhany-Sabunchy-Ramany and Bibi-Eibat fields are approaching exhaustion. Some of the layers, which used to be oil bearing and very productive, yield very little oil and large amounts of water. The gradual increase in the depth of producing wells points to the same fact. At the same time we see that the upper pay sands are drained to a larger extent than the lower beds.

As to the lower horizons of the Baku oil measure—*i.e.*, the second and the Kirmaku divisions—these may be considered to be perfectly virgin.

At Bibi-Eibat the lower horizons of the oil measure are also very rich in oil, as the seven or eight wells carried down below 2,800 ft. brought up oil in gushers.

The chief difficulty in drilling to the deeper pay sand is the presence on both groups of fields of thick water-bearing sands dividing the upper pay sands from the lower virgin strata; besides this, the thickness of clay layers in the lower horizons is considerably less than in the upper horizons and therefore with the increase of depth the isolation of water from the pay sands becomes more and more difficult. The third obstacle lies in the depth at which these lower pay sands occur. Over the greater part of the area under actual exploitation the depth at which the lower pay sands may be worked is from 2,800 to 4,200 ft. It is evident that drilling to such depths, considering the presence of thick water-bearing sands, is far from being an easy matter. But no doubt the improvements which are continually introduced in drilling methods and in the cementation of wells will enable the Baku producers to exploit these deep-lying horizons, probably in the very near future.

In conclusion, I must draw attention to the fact, that the Baku oil field is one of the most remarkable fields on the face of the earth. We see here a number of separate pay-sand layers following one another, all these oil-bearing beds being of considerable capacity. Up to the present time, from an area of 2,500 acres these oil fields have produced about 1,400,000,000 barrels, or 560,000 barrels per acre, and still production continues at the rate of about 52,000,000 barrels per year. And of these 2,500 acres there are still plots of Crown lands which have been left intact.

This enormous accumulation of oil on such a comparatively small area is due to the very high holding capacity of the sands, and also to a very favorable geological formation of the locality—namely, the fact that

the sand layers form a quaquaversal anticlinal, with gently dipping strata on the wings.

Besides the Balakhany-Sabunchy-Ramany and Bibi-Eibat fields, there are other fields on the Apsheron peninsula which are likely to prove very good producing territory. Thus I have already mentioned the Surakhany field, where work was started a few years ago. At the present time this field produces yearly about 4,000,000 barrels of oil, nearly every well sunk to 1,400 to 2,100 ft. proving to be a gusher. The area of this field is not yet defined, but we have abundant data to show that this field is also a dome-shaped anticlinal with its axis running in a north-south direction.

A few miles further east there is another similar dome-shaped uplift where prospecting work is carried on at present.

In the western part of the Apsheron peninsula oil has been found in several localities and prospecting work is carried on. This will show what we have to expect from the western section.

Water Intrusion and Methods of Prevention in California Oil Fields

BY FRANKLYN W. OATMAN, BERKELEY, CAL.

(NEW YORK MEETING, FEBRUARY, 1914)

IN order that the conditions which obtain in an oil well may be readily understood, a brief description of a typical California well and a number of the phenomena accompanying same will be given. That the necessity for the exclusion of water be realized, the effects of water intrusion, a description of methods of prevention, and a discussion of causes of failure will be presented, followed by a summary and recommendations.

Fig. 1 shows a section of a typical well which illustrates the relation of oil sands to overlying strata. It indicates a deep water sand separated from the oil sand by shale, and the proper place for the final shutting off of water. In this well a comparatively thick stratum of compact shale protected the oil from overlying water so that the operation of landing the water string was a simple matter. In some wells the protecting stratum may be only from 3 to 5 ft. thick and very careful operation is necessary in order to land the water string of casing properly and not puncture through to the oil sand. The cases just cited are common, but occasionally, after excluding overlying water, productive oil sands are drilled through in the expectation of finding more productive underlying sand, and a water-bearing stratum is tapped. In this case the problem is the reverse of the normal; water must be prevented from ascending rather than descending.

A discussion of well-drilling methods is not within the scope of this paper, except such operations as pertain to shutting off of water. A brief outline of the several conditions which may accompany drilling follows. Some or all may be present in any particular case. The direct relation of these to prevention of intrusion will be discussed in detail further on.

In drilling, the hole becomes more or less irregular in shape, and rough, and as the casing follows the bit into the well it does not fit snugly against the walls. As a result, water may descend between the casing and walls of the well. If a circulation pump is not used during drilling, the hole is simply punched through and the pulverized material removed from the well by means of a bailer. If circulation is maintained there is a continual flow of water down inside the casing and up around the outside between the pipe and the walls of hole. This keeps an open space around the pipe.

It frequently occurs in drilling that a crooked hole results. As a consequence, the casing may press tightly against one side of the hole with considerable free space on the other, permitting only partial circulation, although water may pass slowly between the casing and the compressed earth on the side that is binding.

Alkali water is encountered in many wells in California oil fields, near the surface and at considerable depth. Some of this water is very highly mineralized, containing large amounts of sulphates, and much hydrogen sulphide. In the Coalinga field, for example, a stratum is encountered not so very far above the oil sands, which contains a black, stinking

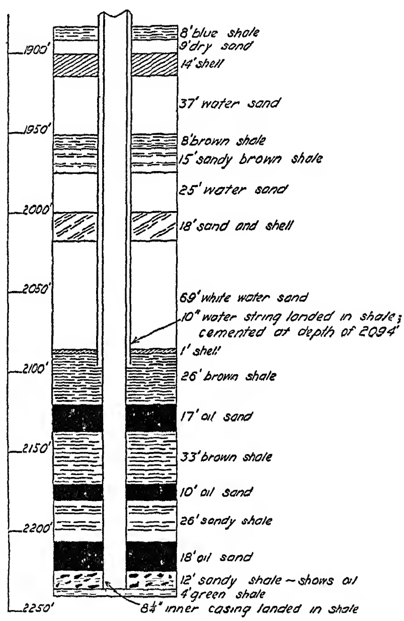

Fig. 1.—Partial Log of a Typical California Oil Well.

sulphur water. This water is dark colored, heavy with sulphates, and strong in hydrogen sulphide. A number of failures in this field have been attributed to the presence of this water. The relation of such waters to the operation of cementing off will be discussed under failures due to alkali water. Very hot water is struck in some places. Its effect on cement will be considered.

In case oil sand is struck considerable oil may collect in the hole, and later affect the cementing operation. Gas under great pressure may be encountered and tend to bubble up through the water in the well. Opposed to gas pressure is the hydrostatic pressure of the water column in the well.

Effect of Water Intrusion

Excluding the water means preventing it from descending or ascending into the oil sands. This must be done to prevent the water from flooding an oil field. In a short time not only the well admitting water to the productive measures but all adjacent wells tapping the same sands would be pumping water and oil. Added to this is the constant menace that the water may increase to such an extent as entirely to displace the oil. In any event, the influx of water forces the gas and oil to rise in the productive measures, thereby causing a serious decline in production.

When water intrudes an oil sand the effect of flooding may be described as follows:

In a new oil field where the gas pressure is high the oil is under pressure, and if water reaches it, the latter descends with difficulty, forming an emulsion.

In an older field where the gas pressure has been greatly reduced the water passes through the sand more readily than the oil. This is because water has less viscosity than oil, and the sand offers less resistance to flow of water. In such a case, the water is believed to flow through regular channels which it forms in the oil sands. A proof of this is offered in the following phenomenon, the experience of a California operator. It became necessary to repair a well, formerly productive, which tapped a rich oil sand. To do this, the casing was filled with water. In a few hours, adjacent wells tapping the same oil sand began to pump water, with very little oil. When the well in question was again put on the beam, it pumped water for some time and gradually the oil increased in amount. The significant fact in this case was that the wells pumped little or no oil, the production being mostly water, although they still tapped a rich oil sand formerly productive. As soon as the water was removed the oil production became normal. From this can be recognized the grave danger to a producing field by flooding.

It sometimes happens that in a region of producing wells a new well may be sunk to the productive sand and abandoned for some reason without proper precautions being taken to prevent water from descending and flooding that sand. The owners of the abandoned well may not be concerned with the effect on adjacent property, but the production of the latter will certainly suffer. Therefore, it is to the interest of all companies in the California oil fields to co-operate and prevent the ruin of their property by flooding resulting from careless operation.

Methods of Excluding Water

As practiced in the principal California oil fields, the methods of excluding water may be classed as temporary and permanent. Perma-

nent exclusion may be obtained by forcing the lower end of a string of casing, called the water string, into an impervious bed above the oil sand; or by placing a water-tight body of cement between the casing and the formation. Of these two methods the first is unsatisfactory and is not to be considered good practice.

Temporary

Regular or special well packers may be employed to prevent temporarily the entrance of water until permanent relief can be found. Such are useful in instances in which the casing may be punctured above the oil sands and water finds entrance to the productive zone through the casing.

Bags of flaxseed, peas, or cereals which swell greatly on absorbing water, forming a compact mass, were formerly introduced in wells to exclude the water temporarily, but are not now used, the cementing method having superseded the use of such.

As a preliminary step to cementing a well in which gas is causing severe agitation, the hole should be bridged by ramming in broken stone, earth, etc. A method successfully used by some operators is to place in the hole a generous plug of the following composition, which has the effect of restraining the gas, temporarily at least. The mixture (parts by weight) is composed of 5 parts red lead, 2½ sand, 2 plaster paris, 2 rosin, and enough boiled linseed oil to make a dense paste. The mass should be allowed to set in the well about 24 hr. before proceeding with cementing.

Permanent

By Use of Drive Shoe.—In sinking a well, a steel drive shoe is attached to lower end of casing. This shoe is slightly larger in external diameter than the casing and has a cutting edge. Before the use of cement it was the custom to land the water string in some compact formation located above the oil measures by forcing the drive shoe into that formation. The well was then continued with a smaller drill, the casing resting on a shelf.

Although this method has been used in some California fields, where certain special conditions obtain, it is not reliable because water generally leaks past the drive shoe and passes into the well. This method may be applied in other fields in which the water string can be landed in an unfractured sticky clay shale.

The drive-shoe method is merely mentioned as a matter of historic interest. The cementing method of excluding water has replaced the former in California, because it has been found to be the only satisfactory one for use in deep wells.

By Use of Portland Cement.—Since the above methods were not always effective, nor of general application, a search for some means to obtain permanent exclusion resulted in the use of Portland cement. It has been used for several years, and when properly manipulated should give the desired result.

The methods in general use for cementing off the water are the tubing, the bailer, and the Perkins. The object of any cementing operation is to obtain a compact collar of cement which will firmly adhere to the casing and so fill all voids resulting from drilling that no water can descend into the oil sands. The operator aims to land the string of casing in a compact bed of shale, which is impervious to water and capable of sustaining the weight of casing.

For example, in the Coalinga field, experience has shown that the blue or brown shale encountered just above the oil sands provides a most suitable final landing place. Note position of this bed as shown in Fig. 1.

Tubing Method.—The following examples illustrate the tubing method of cementing.

Method A.—At the point where the water is to be shut off the hole is reamed out from 4 to 6 in. larger than the pipe for about 40 to 80 ft. from bottom. The water string is raised a foot or so from bottom and water pumped down inside the casing and up to the surface around the outside of the casing. The purpose of this is: To assure the operator that there is free circulation; to wash away the mud, oil, etc., from the sides of the casing and the hole, so that cement may adhere thereto; to open the space around the casing so that a complete ring of cement may form. This water circulation may be continued for a considerable period, sometimes as much as 30 hr. or more, to clean the hole thoroughly. The casing is then raised 2 to 6 ft. from bottom, and a string of tubing (3-in. standard size) with a swedge nipple on the lower end is lowered to within about 2 ft. of the drive shoe. A cast-iron disk, or a packer, fitting close to the inside of the casing, is also on the bottom of the tubing; this is to prevent cement from backing up inside the water string. Cement is then forced into the tubing by a force pump. As soon as all the cement is inside the tubing, a wooden plug is slipped into the tubing, and is forced down on top of and following the cement by the water pump, which now pumps water after the plug to rinse the tubing of cement. See Fig. 2. The pump pressure is usually about 250 lb. when the plug reaches the swedge nipple. Circulation is then stopped, and the operator knows that his tubing is free of cement. The water string is then set on bottom, the casing being spudded into the bottom for a foot or so to prevent cement from rising in it. The well is allowed to stand for a period, varying from 10 to 28 days.

The time of mixing and placing cement varies with the operator. Some companies claim to be able to mix and place all their cement in

from 30 to 40 min.; other companies require an hour or more. The element of time is exceedingly important, as the cement must be placed and allowed to settle before the period of initial set has been passed.

The amount of cement used varies from 2 to 10 tons, according to the practice of the operator and the requirements of a particular case; 3 to 6 tons may be taken as the average amount required.

Cement is mixed with enough water to make the mixture of the consistency of thick gravy, so that it can be readily pumped. Either neat cement or a sand-cement mixture may be used, the former being the most

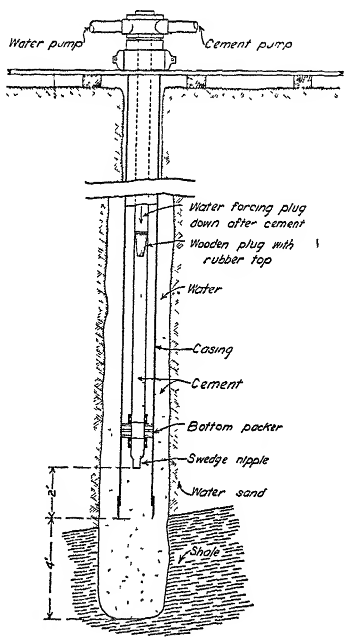

FIG. 2.—THE TUBING METHOD OF CEMENTING WITH BOTTOM PACKER.

favored. If sand is to be employed, 10 to 15 per cent. may be added when mixing. For neat cement the amount of water added is about 60 per cent. of the weight of the cement.

Method B.—This is practically the same as Method A, but the method of packing the bottom of the casing will be particularly described.

The hole is reamed out and prepared as before. The water string is raised a foot or so from bottom and a string of 3-in. tubing lowered therein. Attached to the bottom of the tubing is a Graham packer. This packer is made of cast iron with outside leather packing and fits snugly against the inside of the casing. It contains a self-closing clack valve opening downward. Projecting from the lower side of this packer are three forked

iron strips, as shown in Fig. 3. The prongs of these forks are compressed and lie in the inside of the casing during descent, but spring out when they pass the bottom of the casing. Then on pulling up they hook on to the drive shoe of the casing, and the operator knows that he has reached the bottom of the hole. A wire fastened to the packer keeps the valve open during descent so that water may enter the tubing. When the prongs are pulled up on reaching bottom, this wire is broken and the valve closes.

When water or cement descends through the tubing the valve can open, but pressure from below will close it. On top of and following the cement is a long wooden plug. Water is pumped down, as before, on top of this plug. When the plug reaches the valve it sticks, and the pump

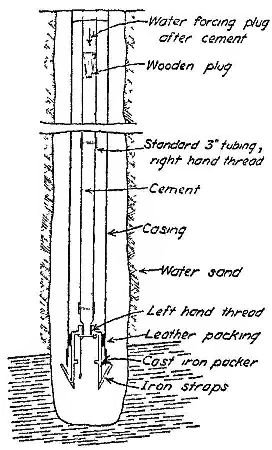

FIG. 3.—TUBING METHOD OF CEMENTING USING GRAHAM PACKER.

pressure rises so that the operator knows that the tube is free of cement. The well is then allowed to stand for the proper period.

There is a left-hand thread between the bottom end of tubing and the packer. The joints of tubing have right-hand thread. To remove the tubing, the string is turned so as to tighten right-hand joints, and this will unscrew it at the bottom.

When drilling is resumed, a few blows from the bit will break the brittle cast-iron packer into small pieces, which soon disappear.

Method C.—This is called the top-packer method. The hole is prepared as before and circulation assured. The casing is suspended from 2 to 6 ft. above the bottom and 3-in. tubing is run in to within 2 ft. of the casing shoe. A packing head is then placed over the top joint of tubing and screwed into the top casing coupling, packing off the space between

the casing and the tubing. When the casing is filled with water and cement is pumped in through the tubing it cannot rise inside the casing and must travel around the shoe and up on the outside.

Bailer Method.—In this method the hole is under-reamed for a distance of about 40 ft. from the bottom and circulation assured. The

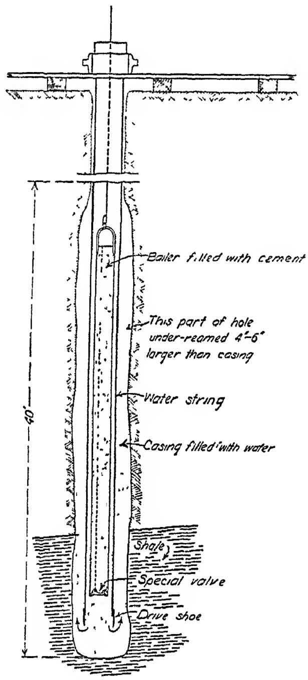

Fig. 4.—The Bailer Method of Cementing.

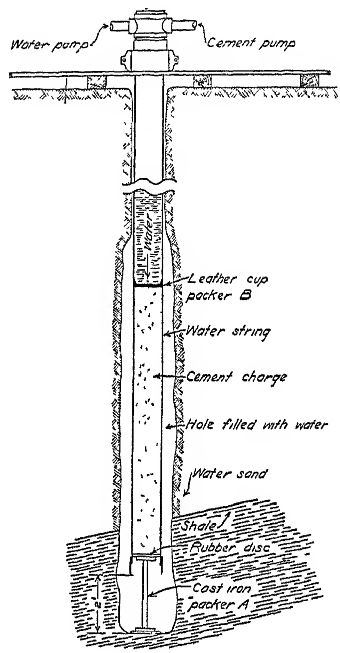

Fig. 5.—The Perkins Method of Cementing.

water string is then raised about 10 ft. from bottom. The cement is mixed at the surface as before, and placed in a large bailer arranged with a special trap so that it will dump on reaching bottom. Usually two loads of a 40-ft. bailer are deposited in the bottom of the hole. The casing is capped and then allowed to drop, forcing the cement up around the casing and into the bottom formation. On opening a tap and releasing the pressure, the casing sinks to the bottom. It is then spudded into the bedding formation. See Fig. 4.

Some companies bail the cement out from inside the casing before it sets; others allow the cement to set and then drill down through it when extending the hole. The best practice is to bail out the cement if the casing is well spudded into the shale. This dispenses with the necessity of drilling out the cement from the interior of the casing, an operation liable to

fracture the cement collar. Instances have been known where the bailer was tripped while being lowered, but such seldom occur.

Perkins Method.—The Perkins method is similar to the tubing method in results, and has been successfully used in California fields. The following description and reference to Fig. 5 will explain the operation.

Circulation is first made sure of. A cast-iron packer, *A*, with flexible rubber disks at top and bottom, is then floated in the water filling the casing. The cement is mixed and pumped into the casing, forcing the packer down. A leather cup packer, *B*, is placed on top of the cement, and on continuing the pumping the charge of cement is forced to the bottom between the two packers. When the lower packer reaches bottom it stops, while the cement is forced past *A* by bending of the rubber disks. All the cement can be thus forced into the hole outside the casing. When packer *B* reaches packer *A* the pressure rises at the pump and the operator knows that the cement has been placed. Pumping is stopped and the water string set on bottom. The well is allowed to stand for the usual period.

When drilling is resumed, packers *A* and *B* are soon broken by blows from the heavy bit and sinking continued.

Discussion of Cementing Methods

The success of all cementing methods depends upon the fact that cement grout is heavier than water and displaces the latter. There should be a long collar of cement around the casing, no matter which method is used. The cement collar should extend some distance up the casing. In some cases the cement runs up for only 25 to 40 ft. Instances have been known where it has been forced 400 ft. or more above the shutting off point. The tubing and Perkins methods are similar and have one advantage in that the large amount of cement used coats the casing for some distance above the bottom of the hole. As this coating may be through the water sand, the cement is believed to form an effective protective coating against deterioration of casing by ground waters. The eating away of casing by chemically active waters, resulting in passage of water to the oil sand, is a very dangerous condition in the oil fields. This is a very strong point in favor of tubing or similar methods.

When the cement has been allowed to harden, the well is bailed dry. If there are no leaks at the bottom, or through holes in the casing, a dry well should result. Drilling may then be resumed. If unsuccessful, the hole must be re-cemented; cases are on record where it has been found necessary to re-cement from two to eight times.

Either the tubing or the Perkins method is applicable in the average case. The bailer method may be used in normal cases, and also when it is necessary to block some hole already existing, or in closing a discarded

hole. The drive-shoe method is applicable in a compact sticky shale unfractured by heavy drilling. One of the large California companies claims to have wells in which the water was successfully shut off by use of the drive-shoe method 10 years ago, and which are still water-tight, but these are very exceptional.

Owing to the rapid eating out of pipe in many California fields, due to bad water, it is of the highest importance that as far as possible a thick coating of cement surround the water string. Many operators to-day are advocating the following operation for permanent protection against water intrusion: Sink the 12-in. casing as far as practicable and then cement off by the tubing method, forcing the cement as near to the surface as possible. Then land the 10-in. water string in a suitable bed above the oil sands, cementing again by the tubing method, forcing the cement well up around the pipe. Run in a string of 6-in. casing, land it 2 to 4 ft. below the 8 in., and cement the space between the 6 in. and 8 in. solid. In this case the bottom of the 6 in. is only a few feet below the 8 in. and in the same impervious shale bed. If this method is adopted the second water string is protected by a heavy ring of cement and if properly done the well should last for many years. This method, or a modification thereof to meet special circumstances, will inevitably be adopted in California to meet the demand that absolute, permanent exclusion be secured.

Discussion of Cement and its Use

The necessity for exclusion of water and the methods in general use for obtaining this result having been presented, the causes of failure of cementing operations and means of reducing failure to a minimum will be discussed. The causes of failure may be grouped as physical and chemical. The first group includes features relating to physical conditions in a well, manipulation, and placing of cement. The second group deals with the chemical behavior of cement under various circumstances, notably: Variation of properties of cement by varying the process of manufacture; effect of alkali and hot waters.

In the oil fields the cement used is required to give a very dense, compact mass, rather than great strength, and must be as resistant to decomposition by alkali water as possible. Chemists have thoroughly studied the cement question, and the results of their investigations are summarized below. Free lime must not be present for it endangers the quality of the cement, because reactions between lime, alumina, and sulphates form a compound which on hydration swells and bursts the cement. Therefore a necessary qualification for cement to be used in oil wells is that there must be no free lime, especially if the cement is exposed to strong sulphate waters. Magnesia behaves similarly to lime in reac-

tion, and may hydrate slowly and finally cause disintegration if present in amounts over 8 to 10 per cent. The period of initial set is influenced by the concentration of alumina. An increase in alumina results in a rapid-setting cement. High aluminous cements are, however, severely attacked by sulphate water. Iron oxide is advantageous in cement subjected to strong sulphate waters because it does not react with calcium sulphate as alumina does, resulting in disintegration. Certain iron-ore cements have been shown to be alkali-proof and disintegrate very slowly on immersion in strong alkali water.

Gypsum may be added to regulate the time of setting. Up to about 2 per cent. it retards setting; beyond 2 per cent. it makes the cement quicker setting. The amount of gypsum should be low in a cement to be used in alkali water.

The Setting of Cement.—This is a process of gradual chemical change arbitrarily divided into three periods: (1) Initial set; (2) final set; (3) hardening. The important condition to be observed in cementing a well is that the cement shall be mixed and placed in the well and have time to settle into a uniform mass before the time of initial set. Suppose a well is cemented by the tubing method, and that the cement is forced up around the casing for a considerable distance while pumping. The cement is then allowed to settle, provided no underground currents or gas bubbles keep it agitated. If the time of initial set is passed before the cement settles out to a uniform mass, then a considerable part of the usefulness and strength has been lost. The success of the work now depends on the final set and hardening. At the best, this will result in a less dense and less resistant product, although it may happen that it is sufficient for water exclusion in a given case. Hot or alkali water, excess of water in mixing, and other points which affect the time of setting will be treated further on.

Long storage may increase or decrease time of setting, depending on the composition, particularly as regards amount of free lime. Some cements, though slow setting when made, become quick setting on storage. This has been known to take place within a few days. After longer periods the original slow setting quality may return. Trouble of this kind is characteristic of light burned cement rich in alumina.

The amount of water used in mixing has an important bearing on rate of setting. Up to a certain limit, the more water used the more the time of setting is increased. The limit comes at about 60 per cent. by weight of water, at which point the cement mixture is saturated.

Since in cementing a well by any of the methods previously described a large excess of water is used in mixing, it is evident that the amount of water finally in the mixture when in place is about 60 per cent. In this event the time of both initial and final set has been greatly prolonged beyond the time of setting under normal surface conditions. This fact is

of importance to the operator because the cement has a longer time in which to settle during the period of initial set.

Considerable experimental work has been done by many investigators to determine the effect of various salts on rate of setting. Calcium chloride, $CaCl_2$, decreases time of set, and if over 2 per cent. by weight is used is likely to so hasten the set as to make the cement difficult to handle. The use of $\frac{1}{2}$ per cent. of sal soda, Na_2CO_3, has been found effective in hastening the set in wells troubled with gas.

Since hot water is encountered in many oil fields, its effect on cement is worthy of notice. In general it may be stated that the time of setting decreases with increasing temperature. The following experiment illustrates this:

Neat Cement, 40 Per Cent. Water

Temperature, degrees F.	84	110	142
Time of initial set, hours	6	$3\frac{1}{2}$	$2\frac{1}{2}$
Time of final set, hours	8	$5\frac{7}{12}$	$3\frac{1}{4}$

The temperature of water in oil wells has been known to go as high as 60° C. or more, which corresponds to 140° F. The above results show that at 142° F. the time of setting is less than half what it was for what may be considered the normal temperature.

It is therefore important to know, when cementing a well, whether hot water will be encountered. If so, its effect on time of setting should be considered.

The following table shows the effect of gypsum on time of initial set of cement with 26 per cent. water:

Time of initial set, in minutes

Amount of gypsum, per cent.	0	1	2	3	6
Sample A	4	258	287	268	84
Sample B	232	477	460	425	40

The advantage of finely ground cement for oil-well work is a question open to discussion. Fine grinding varies the soundness and rate of settlement. Finely ground cement if composed of particles of different relative size, so as to render the voids negligible, will make a more dense product, less pervious to water. The effect of fine grinding on time of initial set may be well illustrated from the following table prepared by Richard K. Meade.[1]

[1] *Proceedings of American Society for Testing Materials*, vol. viii, p. 410 (1908).

	Percentage Passing a No. 200 Sieve					
	75	80	85	90	95	100
No. of Sample	Time of Initial Set, in Minutes:					
1	255	246	192	75	12	2
2	105	106	100	100	22	6
3	120	115	100	95	60	35
4	240	200	182	115	60	30
5	240	210	110	55	15	5

Since cement may have its time of initial set decreased by fine grinding, it may be advantageous to secure such cement for use in oil wells (as those troubled with gas), in which it is desirable to have the cement set rapidly. Finer grinding increases the sand-carrying capacity of cement, which is advantageous in cases where sand is added when cementing a well. The brands of cement most used in California oil fields will pass about 97 per cent. through a 100-mesh screen, and 80 to 85 per cent. through a 200-mesh screen.

Summarizing, finely ground cement should be advantageous in cementing a well, for: It sets quicker, more completely, and is more active; it forms a sounder and more dense mass with greater resistance to action of decomposing alkaline water; it is less permeable to water under high pressure; it can carry more sand. But it costs more, may be harder to procure, and may increase laitance under conditions effective in wells.

Alkali Water

Alkali water is encountered in the oil fields of California. In fact most of the water to be shut off is mineralized to a greater or lesser degree. In some places the water is very heavy with sulphates. Reference has already been made to the "Big Sulphur Water of Coalinga," which is claimed to be the cause of a number of failures in that field.

There has been much discussion as to whether most failures are due to presence of alkali water or to physical conditions. The questions asked by oil men are: Will strong alkali water prevent the cement from setting in the well? Will such water cause later disintegration of cement, resulting in failure of the cementing operation?

Let us see if strong alkali water will prevent the proper setting of cement. To do so, consider the case of an ideal well. Suppose that no conditions such as presence of gas, oil, mud, crooked hole, etc., prevail to prevent setting, except that an exceedingly strong sulphate water is to be cemented off. Also, suppose the cement properly placed before the time of initial set. Under these ideal conditions, if the cement fails to set, such failure may be attributed to the action of alkali water. It is

known that the principal injurious substances in such water are sulphates.

Such ideal conditions, except for hydrostatic pressure, were produced in the laboratory. Western State "Cowboy" brand cement, which is much used by oil men in California, was chosen and tested in solutions of sodium sulphate. Solutions of Na_2SO_4 of 1, 5, 10, and 20 per cent. strength were prepared in large beakers holding about a liter. Cement sludges containing 40 per cent. by weight of the above water solutions were mixed. Each was poured through a tube to the bottom of the beaker containing the solution of same strength as was used in mixing it. This was similar to cementing by the tubing method. After setting for 24 hr., the tests were examined. All set perfectly, except that there was considerable laitance on the surface, and that the upper part of the cement was somewhat softer than is normal. This latter may have been due to delay in hardening due to presence of the salts in the water, and to a large amount of water. The tests were examined from time to time. The cement gradually hardened, giving off much free lime, which on oxidation gave a crust of $CaCO_3$ on the surface. After six weeks, the tests were all about the same in hardness, and showed no visible signs of deterioration. If continued long enough, no doubt the cement immersed in the strong solutions of Na_2SO_4 would have swollen and disintegrated. Tests on briquettes immersed in a 5 per cent. solution of Na_2SO_4 for six months, resulted in complete disintegration of some, and fatal swelling and bursting in others.

The above experiments prove that a good cement will set in a very strong solution of a typical sulphate water, and will harden. If freely exposed to action of such water, however, the cement may disintegrate completely if in a small mass. If cement will set as described above, it should set and harden in the ideal well described. Whether or not the cement may be sufficiently decomposed later by the sulphate water to permit water to work through the mass is a question for further discussion.

If after a well is cemented and allowed to stand for the proper setting period, it cannot be bailed dry inside the casing, but leaks, the operation is a failure. Evidence presented proves that the failure is not due to prevention of setting by the action of the sulphate water. Therefore it must be due to other causes. It is possible that the great hydrostatic pressure of the ground water may be the determining factor in such cases, but I believe that such pressure is much more likely to be effective later on in aiding disintegration.

Cement will likewise set in hot alkali water, although the period of setting is greatly decreased with increase of temperature, as already shown in the discussion on cement.

The disintegrating effect on cement of a large number of salts has been studied, and the cause of disintegration has been explained by Le Chatelier and others. The study of alleged failures due to alkali water is more

difficult in the case of an oil well because of the inaccessibility of the work and the great hydrostatic pressure.

Thorough investigation has revealed the fact that the direct cause of disintegration is the presence of the sulphate ion resulting from presence of such salts as Na_2SO_4, K_2SO_4, $MgSO_4$, $CaSO_4$. Other salts have only a trifling effect, if any. Le Chatelier's theory of disintegration is as follows: When cement hardens, CaO is liberated, which becomes $Ca(OH)_2$. This reacts with the SO_4 present in the water to form $CaSO_4$, which in turn reacts with the calcium aluminate of the cement to form a lime-sulph-aluminate, which swells greatly on hydration, with great increase in volume, causing disintegration of the cement. The composition of this substance is believed to correspond to a lime-alum: $CaAl_2(SO_4)_4.24H_2O$. The crystallizing force of this substance is enormous.

Le Chatelier states that the extent of the disintegration varies directly as the percentage of alumina present in cement. Cement containing 1 to 2 per cent. of Al_2O_3 is practically unaffected. Cement containing 7 to 8 per cent. of Al_2O_3 swells rapidly and disintegrates. He replaced the alumina in cement by oxides which do not react with $CaSO_4$, such as oxides of iron, chromium, and cobalt. The resistance to action of sulphates was then much increased. Iron oxide gives the best effect.

Many analyses have been made of surface alkali waters and their disintegrating effect on cement has been studied. For purposes of comparison typical analyses of strongly alkaline well and surface waters are given. As typical of a strong alkali surface water which has caused great destruction of concrete, the following is an analysis of water from the Sun River project, Great Falls, Mont. The analysis is quoted from an article by J. Y. Jewett.[2]

Substance	Parts per million
$CaSO_4$	1,690
$MgSO_4$	6,870
MgH_2CO_2	305
$MgCl_2$	192
KCl	20
Total solids	9,077
Ignition loss	222

An analysis of well water from the "Big Sulphur Water" of Coalinga oil fields is given as typical of those encountered in California which may act upon cement in a well and tend to cause disintegration.

[2] *Proceeding of American Society for Testing Materials*, vol. viii, p. 480 (1908).

Substance	Parts per million
$NaCl$	1,010
K_2SO_4	170
Na_2SO_4	1,435
$CaSO_4$	141
$MgSO_4$	.....
$CaCO_3$	153
Na_2CO_3	.....
$MgCO_3$	86
Total	2,995
H_2S	Much

It is noticeable that the water of some oil wells is highly mineralized, but in general the percentage of sulphate does not run as high as in the water from Great Falls. There is little doubt but that the water in some wells is rich enough in sulphates to decompose the cement under conditions similar to those acting on the surface. Conditions in a well are favorable to rapid disintegration, since the great hydrostatic pressure tends to force the water into the pores of the cement.

It is quite probable that disintegration of cement does take place, but as an after effect. To further emphasize the fact that strong alkali water has little to do with the original failure, the following case is quoted from the experience of a Coalinga operator.

A failure was reported in which fragments of cement were brought to the surface accompanied by black sulphur water. The cement was said to be "very porous and broken up, as if it had swollen and burst." This may appear to be a case of failure due to disintegration by sulphate, but it later appeared that there was free gas at the bottom of the well. The phenomenon was probably due to action of gas in the well, and will be further discussed under failures due to gas. This is an illustration of a number of failures which have been wrongly credited to action of alkali water.

In summarizing briefly the relation of failures in any well to alkali water, it may be said:

1. Cement will set without regard to concentration of the alkali in water.
2. Conditions appear very favorable for later disintegration of cement, especially as regards effect of pressure, unless retarded by secondary action.
3. With a large sound collar of cement, later disintegration will proceed slowly, because of the size of the collar.
4. The use of alkali-proof iron oxide cement will reduce the chances of disintegration to a minimum; also lime and gypsum should be within the proper limits.
5. Most failures are due to other causes than presence of alkali water.

Circulation

The object of circulating water down inside the casing and up around the outside is to clean out the hole. If the circulation can be made, the operator knows that there is a certain amount of free space around the casing, but this does not prove that the casing is entirely free from contact with the wall. The lower part of the hole is usually under-reamed larger for a considerable distance from the bottom, as explained. This lessens the chances of contact between pipe and ground.

Since the object in cementing is to get a long tight collar of cement entirely inclosing the casing, it is necessary that the pipe be free. When drilling, much fine mud is formed. This must be removed before cementing, so as to leave the casing clean, and to leave the walls of the hole rough and free from sediment. If this is done properly, the cement will then adhere tightly to the casing and completely fill the surrounding space and get the proper purchase. Should there be a coating of oil on the casing, such may be removed by circulation.

If the mud is not properly removed, when the cement is forced through it, the two may be more or less mixed. This is fatal to the proper setting of cement, which may even not set at all.

It sometimes happens during drilling that the hole may get slightly out of line, and so, when cased, the pipe may be in contact on one side, and free on the other. Or blocks of ground may drop in from the wall and press against the casing. When circulating, therefore, the water must dodge these obstacles. It naturally takes the path of least resistance, and so the trouble sometimes is that it wears out a spiral passage through the mud, only partly removing it. Long-continued circulation will tend to increase the size of the channel, which is imperative for success.

Cases are known in which the cementing work was a failure, because of this partial cleaning of the hole. In one instance of failure, the operator, upon pulling the casing and examining it, found a sort of spiral band of cement around and adhering very tightly to the casing. The cement had set well, and was hard, although the water in the well was strongly alkaline. In this case it was evident that the circulating water, instead of washing out all the mud, took the path of least resistance and wore out a channel for itself. Since the cement was forced up in liquid condition, it naturally followed the path formed by water circulation. When it hardened, it only partly filled the original hole, the remainder being occupied by mud. This mud was evidently very pervious to water, which flowed through it to the bottom. Under-reaming and long-continued circulation probably would have made the work successful.

Mixing and Pumping of Cement

It is necessary that the cement be placed as soon as possible after mixing. The usual time for the complete operation of mixing and placing

the cement is about one hour. There is a possibility that the initial set will take place before the cement has been pumped, and therefore it is desirable to place it rapidly, so that it will have as long a time as possible to settle completely around the casing before the end of period of initial set. If a good brand of cement is used, the time of setting of which has been previously determined, failure is not likely to occur owing to premature setting if the cement is quickly mixed and placed.

If the cement is mixed by hand, six to eight men can thoroughly mix a batch of about 5 tons in from 10 to 15 min., stirring with hoes. A mixing box 7 by 12 by 2 ft. will hold about 8 tons of cement. Water may be furnished from a large storage tank and run to the box direct, or a line of hose with a small nozzle may be connected to a pump. After the cement is mixed, it is run through a screen into a small tank, with a 6-in. suction to the cement pump. Some operators use the same pump for circulation and pumping the cement; others prefer one for water circulation and another for cement. The type of pump in general use is the 10 by 5 by 12 in. duplex mud pump commonly found in the oil fields. It is connected to the tubing by a section of $2\frac{1}{2}$ or 3 in. pressure armored hose.

If a mechanical mixing machine is used the cement can be more quickly and uniformly stirred than by hand. A continuous mixing machine is to be recommended, because it insures steady flow, reducing the time of placing. A rotary screw mixer is the type suggested. Most cement is hand mixed as described and generally gives satisfaction.

As regards pumping, it is important that the pumps be stopped as soon as the cement charge is placed, so that the charge will act as a unit and the cement will not be required to settle through a long column of water, and so lose its homogeneity. Provision may be made for this by pumping just enough water after the cement to fill the pipe and clear it of cement, the quantity having been previously measured. Or the pump may be stopped when the pressure rises, indicating that the packer or the plug following the cement charge has reached bottom.

Any method which will decrease the time of mixing and placing the cement is highly desirable and every effort should be made to accomplish this in the least possible time.

Effect of Oil and Gas

In cementing the average well in a field which has been developed to some extent, interference due to the presence of oil or gas is not likely to arise, because the water is cemented off before reaching the productive oil sands. At times minor oil or tar sands are passed through, before reaching the main productive measures, which may affect the cementing operation.

In new fields where the exact relation between water sands and oil

sands has not been determined, the productive measures may be drilled through in the expectation of finding more productive ones below, and water encountered instead. To prevent flooding, this water must be excluded, and this is often a difficult operation, especially if the lower water sand is very close to the oil sand. In this case oil and gas may cause great trouble and even prevent cement from setting.

Experiments were conducted to determine what effect oil might have on the setting of cement. To water mixtures of cement, different percentages of heavy crude asphalt oil were added and thoroughly stirred in. It was found that a uniform mixture resulted, and the oil did not tend to separate readily. Tests mixed as above containing 7, 10, and 20 per cent. were poured under water and allowed to set. The time of setting was considerably lengthened, but the cement set, and hardened as in any other case.

A cement sludge containing 40 per cent. water was mixed and poured into a vessel of crude petroleum. This cement set extremely slowly. After 24 hr. it was still very slushy. A second charge was then poured on top of the first and both allowed to harden. After seven days, the cement was removed for examination. There was a distinct joint between the two charges of cement, and they were easily separable. On breaking, the inside of the cement was found to be stained. The oil was intensified in places, giving a spotted appearance. The cement was hard and compact except for the cleavage plane between the two charges.

The results of this experiment show that cement will set immersed in oil, provided there is sufficient water used in mixing. The cement will be permeated by oil. In case a film of oil is spread over a surface, the cement will not attach itself firmly to that surface, because the skin of oil results in the formation of a plane of cleavage. In a well we would not expect the cement to adhere very firmly to the casing or to the sides of the hole if oil were present which could not be removed by circulation. This might result in failure, the water penetrating along the joints formed due to the film of oil, although the main mass of cement set properly and was very impervious to passage of water.

The following notes, taken from an article in *Mining and Scientific Press*, Nov. 4, 1911, Oil-mixed Portland Cement Mortar and Concrete, by L. W. Page, indicate the effect of oil on time of set.

"The times of initial and final set are delayed by the addition of oil, 10 per cent. oil increasing the time of initial set by 90 per cent., and the time of final set by 60 per cent.

"Oil mixed mortar containing 10 per cent. of oil has very little absorption. Under a pressure of 40 lb. per square inch such a mortar is absolutely watertight.

"The above mixtures were made by first making a water paste, then stirring in the oil, which disappeared when mixed for a few minutes."

A number of cases of failure are reported from the oil fields in wells in which gas was present. There is much good evidence to prove that gas is responsible for failures in wells in which it is active. The following experiences, as related by successful oil operators, are of interest as regards the effect of gas.

One company reported: "We believe that the principal cause of the failure of cement to set properly in a body is due to gas working up through it. In a good shale, undisturbed and unbroken by heavy drilling, the failures are few. In a broken or rotten shale the failures are many. The principal cause of failure in this well is gas working up through the bridge placed on top of the oil sand. In a bailer sent down and filled with water in the bottom of the casing, above the cementing job, and brought to the surface, the water will stand normal for about one minute, then will be agitated greatly by releasing gas. This shows that the water is heavily charged with gas, which in this case could only get into the casing by coming through the cement placed. The cement which was taken from the bottom shows a considerable amount of oil also, probably carried up by the gas."

Another operator reported: "It seems probable that gas may bubble up through the cement and form channels. In one case a job failed, there being much gas in the well. A second charge of cement was placed on top of the first and a tight hole resulted. In some cases even a second repetition was necessary for success."

In order to determine how the setting of cement might be affected by gas bubbling through it, the following experiments were performed.

An agitator was made from a glass bottle of quart size. The bottom was carefully cut out, leaving both ends open, and then secured in a vertical position, neck down. Fittings were provided so that a column of gas or air could be drawn through the apparatus, entering at the bottom, where the neck narrowed down to the lip. A 60 per cent. water cement sludge was then placed in the bottle so as to fill it half full, and air blown in at the bottom. This agitated the cement rather violently in the center of the column, but less so near the sides. This agitation was continued for 16 hr. At the end of that time the agitation was not so violent, confined to the central portion of the column, while there was a compact ring of cement around the face of the bottle. There was much light-colored froth at the surface. The pressure of air was slightly increased, and was continued intermittently until 48 hr. passed. The cement was allowed to remain quiet for several days and then the bottle was broken, and a section cut through the cement. There was a conical space in the main mass, the inside being funnel or crater shaped, pointing to a small hole in the bottom. This hole extended through the part of the cement which was formerly in the neck of the bottle. The hole was open at the lower end, but stopped-up at the upper by a soft, mushy mass of dead

cement. Water drained through the hole on opening the bottom end. In the neck of the bottle were two zones of cement of different qualities. One was the usual cement color, and fairly hard, though easily scratched with a knife. The other was very light colored, and so soft as to be easily scratched by the finger nail. The hole extended through the hard part, being irregular in cross section, and crooked. The main mass of cement was banded, forming zones of dark, harder cement, or of light-colored soft stuff, which was very porous. This cementing operation was of course a failure.

Other similar tests were made. In one case the air pressure was not so strong, and the setting power of the cement was strong enough to cause the mass to "freeze" and shut off the air. On cutting this test piece, a hole was found in the lower part which did not extend up beyond the narrow part of the bottle; likewise the zones of "hard" and "soft" cement were found.

In both the above cases, there was considerable porous vesicular froth, like spongy pumice, on the surface. This was light colored and very soft. Reference has already been made to "spongy cement" brought up in a bailer with sulphur water. The operator thought that the cause of the failure might have been disintegration due to sulphates, but it was probably due to agitation by gas, which was present in the well.

The results of the above experiments show that if the gas pressure is sufficient, the cement may be kept continually agitated, and so all cohesion between particles lost, in which case a slush of inert cement results which cannot set. If the agitation be less violent, the cement may set in part, and gas channels form through it, which may even be entirely closed later, as setting proceeds.

In an oil well the gas may be under great pressure, but there is also a great hydrostatic pressure tending to counteract this. If the gas pressure is excessive, it will work its way through the cement. In case of cementing a well in which a hole already exists through which gas may rise, the hole should first be bridged so as to exclude the gas. Then the well should be cemented by one of the methods described.

Summary

Operations for shutting off water include the use of flaxseed, etc., packers, the drive-shoe method, and use of cement by any one of several methods. The only method discussed at any length in this paper is the one making use of Portland cement. While the other methods have their application, they have failed satisfactorily to meet conditions existing in California fields.

It is recognized that exclusion of water from oil sands is of paramount

importance, and for this purpose the cementing method is standard practice in California.

The composition of all standard Portland cement is practically the same. All cements in general use must pass standard specifications for composition, strength, soundness, etc. Cements may differ greatly in percentage of certain compounds which they contain. The presence or absence of certain compounds affects the various properties of cement in several ways, some being deleterious. The properties of cement may be greatly influenced by variation of operations during manufacture, such as degree of burning and fineness of grinding, or use of gypsum.

There has been much study given by cement manufacturers to the problem of cementing oil wells, and efforts have been made to prepare special cements for this purpose.

The deleterious effect of alkali water is due to the presence of the sulphates contained in it. When cement hardens, the lime liberated forms calcium sulphate, which results in formation of a calcium-sulph-aluminate or lime-alum. This hydrates to a high degree, with great increase in volume, which may result in the disintegration of the cement. Cement will set in very strong alkali water but may be decomposed later.

For cement to be used in alkali water note the following: There must be no free lime; lime content must be kept low; amount of gypsum added must be a minimum; extent of disintegration varies directly as percentage of alumina, therefore it must be kept low; iron may be used to replace alumina; fine grinding increases soundness.

Setting of cement may be varied by: Composition, thoroughness of grinding raw material, degree of calcination, fineness, age, regulators such as gypsum, amount of water used in mixing, temperature, oil, and presence of foreign salts such as are found in sea water.

When cement is deposited under water, the finer part, which is really the most active if properly combined, may float to the surface and form inert, porous laitance. Cement will set properly in a well, if the interfering conditions are neutralized. Some well waters are much stronger than surface alkali water which have caused failure, and therefore we should expect ultimate deterioration of the cement in a well, to a certain extent. This may be counteracted by chemical process, or the cement may deteriorate so slowly that the wells in a field may be exhausted before water breaks in. Pressure is believed to intensify disintegration by alkali water.

In cementing, circulation is necessary before placing the cement, in order to clean the hole, permit the cement to fill all the space, and to become well bonded to the casing and sides of hole. Circulation should be thorough and long continued, lasting as much as 30 hr., or more if necessary, to clean the hole.

Mixing and pumping are important factors in cementing a well and

must proceed with all due haste. Cement should be rapidly mixed, and placed before the time of initial set has been reached. The cement can be pumped thicker than is now the custom, and therefore less water should be used in mixing. A mechanical mixer is strongly recommended.

Oil does not appear to prevent the setting of cement, nor decrease its strength materially, but it increases the time of setting. It renders cement impervious to water, if stirred in, but may cause surfaces of separation in the cement due to films of oil, along which water may pass.

Gas is probably the chief obstacle to the satisfactory setting of cement. Gas may entirely prevent cement from setting; or it may blow holes through the cement, allowing the main part to set; or the setting power of cement may overcome the disturbing action of gas.

It is possible to regulate the time of setting of cement within safe limits. In a well troubled with gas it may be desirable to hasten the setting by use of regulators such as sodium carbonate or calcium chloride.

The water string must be landed in a bed strong enough to support its weight. The bed should be a thick stratum of shale whenever possible.

Crooked holes are probably the cause of many failures, because such prevent clear circulation, and an even distribution of the cement entirely around the pipe.

The pumping of gas, oil, and sand from a producing well gradually reduces the pressure in the productive measure which aids in supporting the overlying impervious bed of shale in which the water string may be landed. The formation may arch, or it may drop down, enlarging the hole. If the upper beds are thin, they may fracture and water may flow through into the productive zone. As a result, a producing field may be flooded beyond the control of operators. Such a phenomenon is not likely to appear for some time in the California fields, since the gas pressure still remains relatively high.

Discussion

Arthur Knapp, Ardmore, Pa. (communication to the Secretary*).—*Cementing.*—I believe that the washing of a well with clear water is, in general, a very bad thing. There are probably formations that will stand up after being washed with clear water, but my experience in California and elsewhere has been, that to wash a well with anything but a well-mixed mud would stick the casing before cementing could be accomplished. The mud is the only thing that will wash the oil out of the hole and hold back the gas. Neat cement is heavy enough to displace the mud adhering to the casing and give the desired contact between cement and casing. Further, any well in which the circulation cannot be established in 3 hr. is not in a condition to be cemented.

*Received Mar. 3, 1914.

The casing should be removed and the hole reamed. Circulation for a long period of time serves only to cut deeper channels around the casing and does not clear the entire circumference.

Method A.—The operator can never be sure of a successful cementing job in using this method, for the reason that, with the packer outside and the plug inside of the tubing, the casing is closed almost water tight, and on pulling the tubing the cement will be pumped back into the casing. No seat can be made that will withstand this suction. The tubing being plugged at the bottom, the string will have to be pulled wet. This is a very bad feature, especially in the long strings, as it puts an unwarranted strain on the tubing if an attempt is made to pull the tubing fast. It also more than doubles the time of pulling.

Method B.—To have success with this method, the packer must be *absolutely* tight, otherwise the tubing will be cemented in. As the chances are there will be at least a small leak, it is well to take precautions to prevent the casing from being cemented in. Either the tubing must be removed or the left-hand thread must be on a connection further up the hole. The bottom 4 to 8 ft. of the tubing may be made of cast iron with longitudinal flutes to make it light enough to be easily broken. This method is open to the same objection—that the string will have to be pulled wet.

Perkins Method.—This method can only be used in a few wells where conditions for cementing are ideal. Under average conditions the casing has to be pulled more than 3 or 4 ft. off of bottom, which makes the cast-iron packer too long. Also in most cases the casing has to be moved up and down as the heavy cement is being pumped up outside of the casing. The second packer, *B*, if made as shown would stick and turn sideways, allowing the cement to pass it. The cast-iron packer is not easily broken. The stem being bedded in cement, it is in a condition to resist being broken by ordinary blows. There is great danger of breaking the seat while drilling out cement alone and the iron adds materially to the amount of drilling necessary.

Cementing Oil and Gas Wells

BY I. N. KNAPP, ARDMORE, PA.

(New York Meeting, February, 1914)

Foreword

I HEREWITH present some notes on the use of Portland cement to cement in the casing, and for plugging, to exclude water from oil and gas wells, and the methods employed. I have used my best efforts to make each step of the operation of cementing wells perfectly clear. The information is the result of actual experience and observation. The illustrations are from original drawings made especially for this paper.

Portland Cement

It is not necessary to discuss here the manufacture of cement. Any established brand of the slower setting Portland cements may be purchased with the confidence that it will harden, if properly used, and exclude water from and plug wells efficiently.

Setting.—By the setting of cement is meant its initial change from a soft or plastic mortar to a friable solid. After the cement has become thoroughly set it is still very weak and can be readily pulverized in the fingers. Setting is thought to be effected by the crystallizing out of the silicate and the aluminate of lime, which are soluble in water in their anhydrous form. After dissolving in the water they pass to the hydrated state, in which they are insoluble, and hence are precipitated in a crystalline form.

Ordinarily neat Portland cement mortar remains perfectly plastic for from 1 to 1½ hr. after mixing with water at about 70° F. A higher temperature accelerates and a lower retards setting.

Hardening.—This is due to a continual crystallization of salts from solution, and to further chemical and physical changes which develop slowly, but which continue for long periods of time.

Testing.—It is no more necessary for an operator to go into the scientific testing of cement to be used in a well than to so test the pipe used. He must depend for the quality of each on the tests and reliability of the manufacturer. Cement or pipe may be damaged in shipment so

as to be unfit for use and such damaged material can easily be avoided by proper inspection.

A practical test of cement can be made in advance of its use for this purpose by filling a common galvanized-iron bucket one-third full of water and stirring in neat cement until the mixture is as stiff as it can be made and still be fluid enough to pour or pump. Then fill several tin cans (old fruit cans will do) with the mixture and at once immerse these samples in water. Take out one sample in 24 hr. and examine for set and hardness, another in 48 hr., and so on daily for a week.

Thus a fair idea of how a given cement will act in use may be formed. It is a good plan to take samples, in a similar way, of each batch of cement as run in the well, and place in water. Examinations of such samples from time to time will give a fair idea of how the cement in the well is hardening.

When Cementing is Required

If any formation does not give a satisfactory seat for a casing shoe, a wall packer, or a plug to exclude water from a well it becomes necessary to use a hydraulic cement.

Portland cement mortars are best adapted for the purpose and neat cement only should be used in cementing in casing, for reasons given later.

Initial Rock Pressures

The initial rock pressure of any oil or gas field is in general less than the hydraulic head of 43 lb. per 100 ft. of depth to the productive horizon.

Mud Pressure

Water can easily be ladened with clays so the mud mixture will weigh 33 per cent. more than the same volume of water or give a head of 57 lb. per 100 ft., or a margin of safety of 14 lb. on each 100 ft. of depth over any possible gas pressure or probable water pressure.

Use of Mud in Cementing and Drilling

It is necessary to use a mud mixture in any well to be cemented so as to exclude all oil, gas, or ground water, and such mud is circulated and made to carry the cement to place but not to mix with it.

Mud-ladened water is used in drilling by the hydraulic rotary method to seal off all porous strata immediately as encountered by the drill; also to counterbalance any tendency of ground water, oil, or gas to run into the hole.

It is fundamental in drilling by the method mentioned that such mud circulation must go down through the drill pipe and bit and up the walls of the well and overflow to a mud pit at the surface.

Plastic materials such as are cut up by the bit and carried up the hole by the circulation are by the wobble of the drill pipe plastered and rolled into the walls of the well, thus giving any sand strata encountered a plastic covering.

Wells in unconsolidated materials consisting of sand, gravel, mud, and clay skilfully drilled by this method and kept full of mud at all times do not cave when the drill pipe is withdrawn and will remain clear for days so a pipe can be run to bottom without being "pumped down" and the mud circulation restored preparatory to cementing.

There are in very rare cases coarsely porous or cavernous limestones that cannot be mudded off in the usual way.

Capt. A. F. Lucas, in his early experimental drilling in Louisiana and Texas, demonstrated some 15 years ago the use of mud in drilling soft formations to keep the holes in shape and overcome gas and water pressures, and its use became general in the Texas and Louisiana oil fields some 12 years ago, and since in California. I mention this because the use of mud in drilling is now being exploited by the press and magazines as a recent invention of employees of the Bureau of Mines.

Results with the Use of Mud

As a practical matter, drilling with the hydraulic rotary method and using 25 per cent. of mud, I have repeatedly sunk through a gas horizon between 1,500 and 1,600 ft. deep, where there was a measured gas pressure of 650 lb. per square inch, set a screen in this horizon and cemented in a casing above the screen without a bubble of gas showing, and not until the pressure was reduced by bailing of the well did gas show.

Also, by the same method I have drilled through a known artesian water-bearing horizon between 1,900 and 2,000 ft. in depth without any sign of its existence, such as increase in the overflow, or of much loss of mud to the porous strata. In this water well a 6⅝-in. casing was set at about 1,880 ft. with a rubber wall packer and then drilled to 2,007 ft., when clear fresh water was pumped in through the drill pipe. When the mud was washed out the well began to flow and the drill pipe was withdrawn. This well threw out considerable sand, shells, and pieces of rock, possibly 30 or 40 cu. yd. in two days. In the course of a week the water ran practically clear and reached a steady flow of about 450 gal. per minute at the surface and gave a static head of about 80 ft. It had 80 ft. of surface casing and was then drilled 1,800 ft. without difficulty, passing three known water-bearing horizons and many loose sand beds, but the hole being always kept full of mud did not cave and the drill pipe could be left in over night with no sign of sticking.

Also, wells are frequently drilled into an oil-bearing horizon without showing a sign of oil, the only guide being the known depth to the oil sand in adjacent wells and the taste of oil in the particles of old sand in the overflow.

This brings out the extreme difficulty in prospecting for oil, gas, or water using the hydraulic rotary method of drilling.

Preparation for Cementing in Casing

A well properly drilled by the method before mentioned and kept full of mud is in perfect condition for cementing. Wells drilled by other methods should be lubricated or filled with mud. Before running in the casing it is best to make sure such casing will go to the bottom and turn freely in the hole. This can be done by running in say three joints of the size of casing to be used on a string of drill pipe to the bottom of the hole. It may be necessary to put a rotary shoe on the end of the casing for removing lumps or straightening crooks in the hole. When the pipe is at bottom a proper mud circulation can be established and all water (salt, alkaline, or potable) as well as any oil or gas can be completely excluded and the well brought to condition for successful cementing.

The amount of. cement to be provided may be roughly estimated by assuming that one sack (95 lb.) of neat cement mixture will fill 1.25 cu. ft. of space.

If, for instance, an 8-in. pipe is to be set in an 11-in. hole it will take between 20 and 25 sacks of neat cement to fill the calculated space for 100 ft. There should be provided a mixing box about 5 ft. wide by 8 ft. long by 18 in. deep, with gate at one end to draw off the mixed cement, two cementing plugs, bottom and top (see Fig. 1), two mortar hoes, four shovels, two galvanized-iron buckets, and a barrel to dip water from; also some sort of screen to pass the dry cement through to break up and take out lumps before mixing. Six men with a box of the size named and with the tools indicated will mix 10 batches of eight sacks each in 1 hr. It is desirable to get the mixed cement in place as quickly as possible and 1 to $1\frac{1}{2}$ hr. is about the limit of time in which cement may be mixed for any one job of casing cementing and run in place. If more than 80 sacks of cement are required, a larger mixing box, or two boxes and more men, or a machine cement mixer will be required.

Mixing Cement Mortars

It is impracticable to specify any particular percentage of water to be used in mixing cement neat or with sand. The best guide is to use the least possible amount of water practical for the work in hand.

As hydraulic cements require water to cause them to set and they will also harden immersed in water it is a common error to suppose they cannot be harmed by an excess of water. Experiments show that any

excess in mixing is weakening in effect and retards setting and hardening. In fact, a large excess of water with prolonged mixing makes a mortar that will not properly harden at all.

If for instance eight sacks of cement are mixed with 18 buckets of water and the mixture works up too thin reduce next batch to say 16 buckets. In all cases make some measure of the water to get a uniform mixture of cement going into the hole.

Methods of Cementing in Well Casing and Plugging Wells

There are several methods of doing this, such as: (1) Lowering the cement mixture in a dump bailer, particularly for plugging wells. (2) Pumping the mixture through a tubing properly arranged to force such mixture outside the casing. (3) Using two cementing plugs and pouring

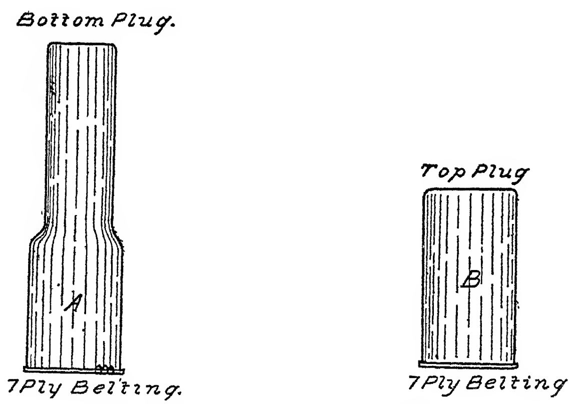

Fig. 1.—Cementing Plugs.

or pumping the mixture in the casing and forcing it down and up outside the casing by pump pressure.

The first method is unreliable and uncertain even in plugging a wet hole. Its use should not be attempted to cement in casing.

The second method is open to the objection of having a string of tubing to manipulate with the casing to be set and as ordinarily used with one cementing plug gives a wet string of tubing (pipe full of water) to pull out.

The third method of using two cementing plugs and displacing the mud with cement by gravity or pumping, as hereinafter described, is in my experience the best for general purposes, as it can be used with the certainty that the cement will be forced by pump pressure into the space between the casing and wall of the well in the shortest possible time and with the least chance of contamination of the cement mixture. There are other methods of cementing with which I am not familiar.

The plugs, Fig. 1, are made of any soft wood that will drill out easily

and of a diameter to pass freely through the pipe in which they are to be used.

The bottom plug (*A*) should be 30 to 36 in. long, to run in a 6 or 8 in. pipe, and other sizes in proportion. The full-size portion of the plug should be 6 or 8 in. long and the diameter then reduced to 4 or 5 in. for the rest of its length.

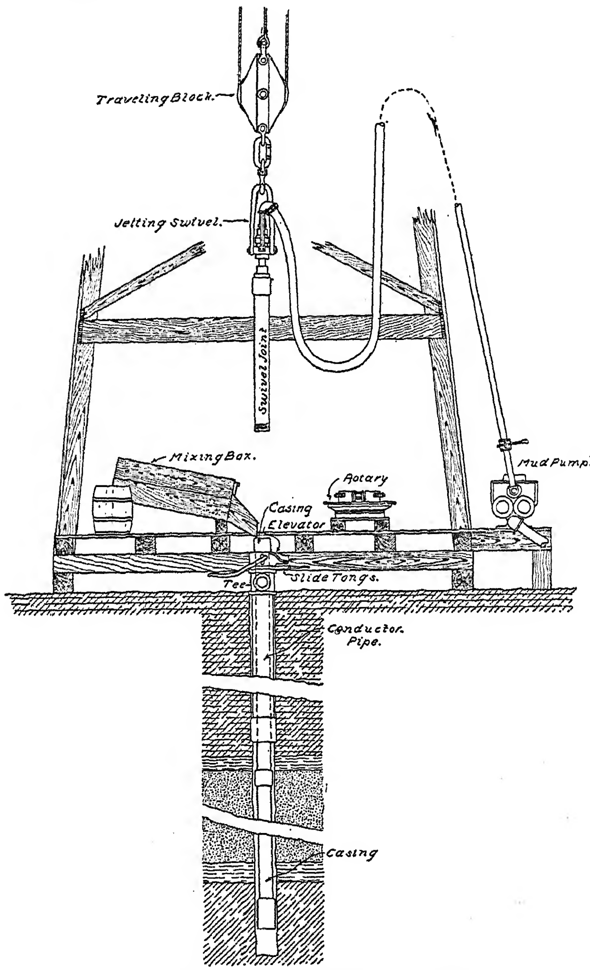

Fig. 2.—Introducing Cement by Gravity.

The top plug (*B*) should be about 8 or 10 in. long for the same sized pipes. Both plugs are faced on the bottom ends with one thickness of 7-ply rubber belting so that they will fit snugly in the casing. These pieces of belting act as scavengers; the one on plug *A* cleans the inside of the pipe of mud as it descends so as not to adulterate the cement; the one on plug *B* tends to keep all the cement pushed ahead of it.

Explanation of Cementing Operations

Fig. 2 indicates how the cement may be introduced into the well by gravity. It shows the lower panel of a derrick with mud pump and connections to jetting swivel, also the traveling block. The rotary is set to one side. A conductor pipe is indicated as set in the well with the top coupling replaced with a tee. The overflow from the well may thus be piped through the conductor pipe and tee to the outside of the derrick. In running the casing, as shown, into the well, the cementing plug *A* should be run through each joint as it is hoisted up in the derrick to be connected, in order to make sure that there are no blisters, dents, or other obstructions in them. The casing is lowered to bottom, marked,

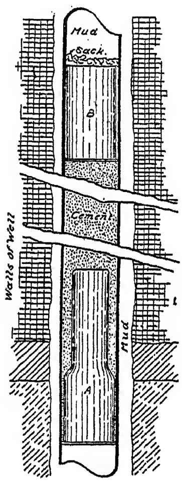

Fig. 3.—Cement between Plugs. Passing down Pipe.

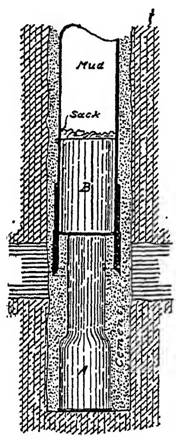

Fig. 4.—Cement in Place. Plugs Meet.

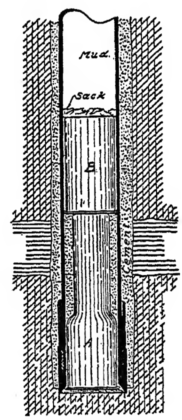

Fig. 5.—Casing Set on Bottom. Cementing Completed.

pulled back just enough so the mud will circulate freely by pumping, and again marked.

After the mud in the well and pit is evenly tempered by circulation, the casing is hung on the slide tongs and elevators placed on the tee on the conductor pipe just under the derrick floor. The swivel joint is unscrewed and set back. In order that the casing will take the cement by gravity the well is bailed down about 200 ft. by displacing the mud with the drill pipe or by bailing in the regular way.

If there is danger in bailing of a gas blow-out or a cave-in from water pressures then other methods must be employed as hereinafter described.

The well and casing should be kept covered at all times so that nothing can fall into the hole. After bailing, the swivel joint is hooked on again and hoisted out of the way to be ready for instant use.

The casing is indicated in the figure in place ready for cementing. The mixing box is placed so that when the end gate is opened the mixed cement will flow into the top of the casing. The water barrel is placed conveniently near and means for filling it quickly must be provided. The cement required should be stacked on the derrick floor and all the necessary tools assembled.

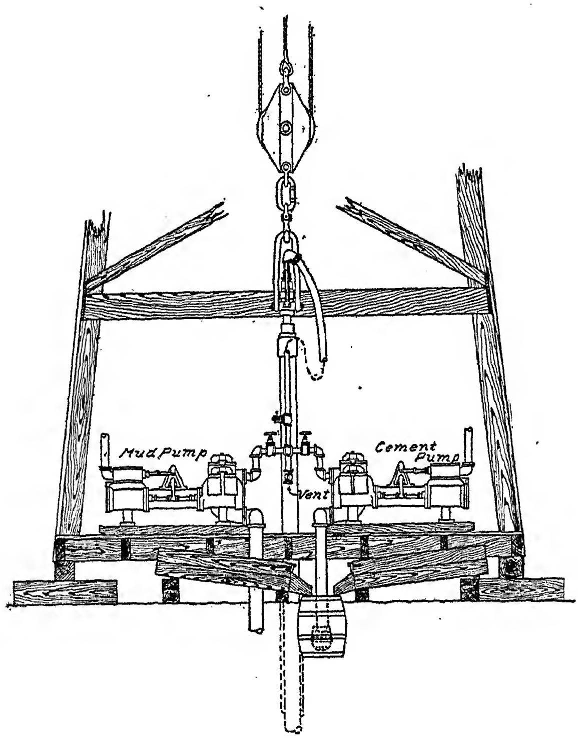

FIG. 6.—INTRODUCING CEMENT BY PUMPING.

The dry cement should be dumped from the sack on to a screen, temporarily placed over the mixing box.

It should not be attempted by this method to put in more than 80 sacks (95 lb. each), as this is about the limit that can be mixed in one hour, with seven men and the appliances mentioned. Everything being ready, the first batch (8 sacks) is mixed, the cover taken off the casing, the plug *A* dropped in small end up, and the cement mixture run in. It is best to pass it through a wire screen ($\frac{3}{8}$-in. mesh) as it flows into the casing, so as to break up any dry lumps.

The succeeding batches are mixed and run in as rapidly as possible. The neat-cement mixture being much the heavier will force the mud down and then up outside the casing. If the casing is hung up more than 12 or 18 in. from bottom, care must be taken not to push the plug *A* below the casing before being brought to the position as shown in Fig. 4.

The required amount of cement having been put in, the plug *B* is dropped in with a cement sack on it as a packer against the pump pressure, the swivel joint connected, the elevator and slide tongs removed, the casing lowered to 12 or 18 in. off bottom and the mud pump started.

After the mud pump has run long enough to fill the swivel pipe and some pressure is shown by the pump gauge it should be stopped and the vent cock, indicated in Fig. 6, opened to let out the imprisoned air. If air is allowed to remain in the casing, or if the suction pipe of the pump or the piston rod packing leaks, such air becomes highly compressed into bubbles in the mud and may cause trouble. Meantime the mud pit is stirred up to make the descending column of mud as heavy as possible to counterbalance the cement column outside the casing. The number of revolutions required for the pump to fill the casing should be calculated and count kept to anticipate about when the cementing plugs should meet.

The cement column is forced by the pump down the casing between the two plugs as indicated by Fig. 3. When the first plug gets to the bottom of the well it goes partly out of the casing as indicated by *A*, Fig. 4, and allows the cement to pass outward and up between the casing and the walls of the well. The cement floats the mud and it is pushed upward by the pump pressure.

When the plug *B* meets the plug *A*, as indicated in Fig. 4, the cement is all out of the casing and the pump stops short by reason of the plug obstruction and the sack packer. The casing should now be given a few turns in the hole to distribute the cement. This can easily be done by two men with a chain tongs. The pump pressure remains on and the casing is set on bottom as indicated by Fig. 5.

The vent is then opened and there should be only a slight back flow, say a barrel of mud, if all air has been vented at the proper time, and the casing shoe is tight. It will be necessary to hold the pump pressure for 24 hr. if there is a strong back flow.

Objections to Cementing by Gravity

This method requires a reduction of the mud head in the well by bailing and gives opportunity for a gas blow out or for oil or ground waters to enter and cave the well.

Also, the lower end of the casing is open, which may act as a scraper against the walls of the well and the casing may become filled with thick mud enough to prevent the passage of the plugs. It is the practice of some, after a string of casing with the lower end open is run in and the

mud circulation established, to hang up the casing, unscrew the swivel joint, throw in a cement sack and pump it down to make sure the casing is clear before cementing.

If there is no danger in bailing the well down, or in plugging the lower end of the casing with the thick stuff, and 80 sacks or less of cement is to be used, the gravity method is, I think, the best that can be devised.

Necessity of Using Neat Cement

By the means described the neat cement reaches the bottom of the casing with but little if any contamination.

The only means that we have of scavenging the outside of the casing and walls of the well is by floating the mud up and displacing it with the cement mixture.

The heavier the cement the better this action, hence it is desirable to use a cement neat and not reduce it with sand. The cement gets contaminated and mixed to an unknown degree with the mud clinging to the outside of the casing and the walls of the well, which also makes the use of a neat cement practically necessary.

Fig. 6 indicates a general surface arrangement for pumping the cement into the casing. The view is at right angles to that shown in Fig. 2, with two pumps set as commonly used in rotary drilling.

To increase the cement-mixing facilities, two mixing boxes can be used as shown, or a machine mixer employed. The mixed cement is drawn into a barrel, sunk below the surface. The suction pipe of the pump to the right is extended into the cement barrel and the pump to the left has its suction opening in the mud pit (not shown).

The manipulation is the same as in the gravity method of putting in the cement, except that when the plug *A* has been dropped in, the swivel joint is again connected, and the cement pumped in. When the cement is all in, the vent cock is opened; air will be drawn in because the descending column of cement will push ahead the lighter mud and make a vacuum.

The swivel pipe is then disconnected, the plug *B* and sack put in; the pipe is again connected, and the mud pumping started. I usually arrange for the mud pump to discharge into the cement barrel so that the cementing pump will run on mud and thus clean itself and the connections of cement. Since the surface of the cement may fall 100 ft. or more and the casing fill with air when opened, it is essential to vent this air, after the pump gauge shows some pressure, as before described.

Advantages of Pumping Method

By this method no bailing of the well is required, so the danger from blow-outs and cave-ins is eliminated. Also, a much larger quantity of cement may be handled in a given time than can be run in by gravity.

Improvement on the Cementing Methods Described

The bottom cementing plug *A* has to pass partly out of the lower end of the casing in order to become operative by the common method and this prevents the use of a back-pressure valve. As the use of such valve together with two cementing plugs was desirable in deep (2,000 ft.) well cementing operations, I invented a method for the simultaneous use of both, as shown in operation in Fig. 7.

This apparatus consists of a double-swedged, by-pass nipple (if for an 8-in. string) made of a piece of 9-in. pipe, about 24 in. long, swedged to 8 in., threaded on both ends and couplings screwed on. Near one end of the 9-in. section two brass bars are put across at right angles, thus forming a rest for the bottom plug, and when the plug is in the position shown the cement is by-passed so the plugs can meet.

The brass bars can be made of $\frac{3}{4}$-in. brass pipe. They must be substantial, since the pump pressure may rise to 400 lb. and throw 10 tons pressure on them when the plugs meet. A back-pressure valve is screwed into the bottom coupling on the by-pass nipple as shown in Fig. 7. This should be a substantial brass valve for deep work. The bars and valve are made of brass so that they can be easily drilled out, with the wooden plugs, at the proper time.

Under the back-pressure valve is fitted a 9 to 8 in. swedged nipple not threaded on the 9-in. end. This acts as a casing shoe and protects the valve.

The two couplings on the by-pass nipple should be screwed up as tight as possible and then pinned or riveted in each thread. When the wooden plugs, brass bars, valve, and cement are being drilled out there is a possible danger that these threads may work loose by the action of the drill and the parts unscrew. This would make trouble and should be avoided.

Advantage of Using the Double-Swedged Nipple

This invention (not patented) prevents the possible accidental passage of the cementing plugs out of the casing and permits the use of a back-pressure valve. This valve prevents thick mud from being forced back into the casing. The casing can be partly floated, thus making a long string much easier to handle. The casing can be bailed down to take any quantity of cement by gravity without endangering the well, also the cement mixture after passing the valve cannot flow back into the casing. The cementing operation may be done by gravity or pumping as before described.

Setting Screen and Cementing Casing Above

When casing cementing is required, it is usually necessary also to set a screen, to make a proper test for oil or gas or bring a well in from a

known horizon. In such cases I prefer to set a screen the full size of the casing required, for the closer the screen fits to the walls of the well the better for the well.

The screen with two joints of the same size casing above may be run in on a string of drill pipe.

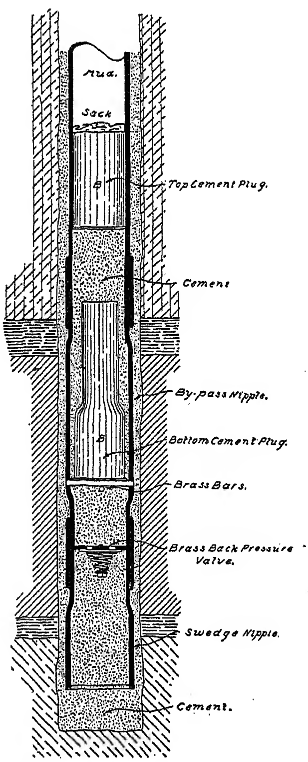

Fig. 7.—Double Swedged Nipple and Back Pressure Valve.

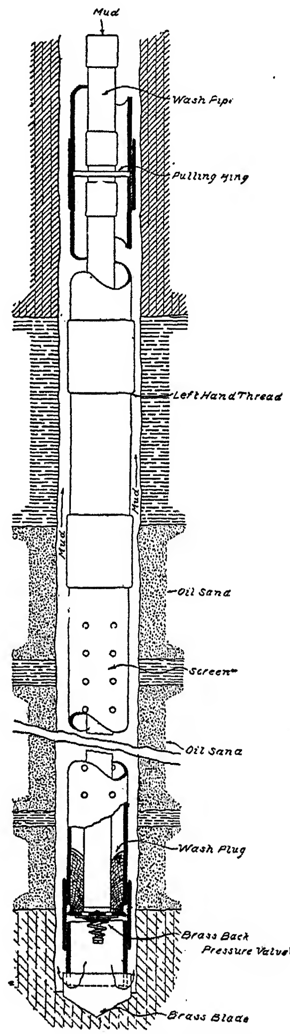

Fig. 8.—Screen in Place.

Fig. 8 shows a screen set in place with all necessary fitting. The brass blade shown at the very bottom is to produce friction in order that the left-hand thread at the top of the screen may be easily unscrewed at the proper time. The short one-thread nipple is to hold the brass

blade and protect the back-pressure valve. This valve is for the purpose before described and permanently closes the lower end of the screen when set. The wash plug in the lower end of the screen serves as a guide and packer to the wash pipe. The function of the wash pipe is to carry all the mud down through the screen and the back-pressure valve so it may pass up outside the screen and casing.

The screen may be of any size or length and made with drill holes only or wire wound to any mesh desired. At the top of the screen is a left-hand nipple 2 or 3 ft. long with the left-hand thread up. By putting the proper tension on the drill pipe and turning, the left-hand thread unscrews and leaves the screen in the hole. The wash pipe is pulled out by the pulling ring.

When the coupling (6 or 8 in.) containing the pulling ring is landed on the elevators at the surface and the joint above unscrewed then the wash-pipe elevators (2 or 2½ in.) may be put on under the top coupling of the string and the wash pipe pulled.

Plugging Top of Screen for Cementing

A soft wooden plug about 20 in. long is made as shown in Fig. 9. The bottom of the plug is made conical as a guide in entering and the body cylindrical to fit tight into the screen nipple, which has a left-hand thread.

The top is rounded over to guide the swedge nipple that is later placed to fit down over the left-hand thread. A 1¼-in. vent hole is bored through the axis of the plug in order to allow mud to flow back into the drill pipe in setting the plug.

A countersink 6 in. deep is made in the top of the plug so that it may be fitted on the end of the (4-in.) drill pipe. A piece of leather is nailed over the vent hole in the bottom of the countersink so as to make a flap valve.

The plug is then run in on a string of drill pipe to bottom.

I have found by experience that enough loose material will be pushed ahead of the plug to pack efficiently outside the left-hand nipple so that no cement will flow down outside the screen in cementing. Pump pressure is put on the drill pipe, which closes the flap valve in top of the plug. The string is raised and the drill pipe pulls out of the plug, an immediate fall of pressure being shown by the pump gauge, indicating that the plug is left in place.

The string of pipe is pulled out and the well is then in shape for running in a string of casing and cementing.

Cementing in the Casing Above the Screen

On this string should be a by-pass nipple, as previously described. Whether a back-pressure valve is to be used or not is determined by the

depth and condition of the well. The string (if 8-in.) should have on its bottom end a 9 to 8 in. swedged nipple. The 9-in. end should be cut with an offset and the lip thus formed bellied out slightly as indicated in Fig. 10. The purpose of this lip is to guide the plug and screen in line by turning the casing and to give a "feeling" which will indicate whether the swedge nipple is resting on top of the plug or has slipped down over the left-hand thread as it should. The string is lowered to bottom and marked, then pulled up until the circulation of mud is good.

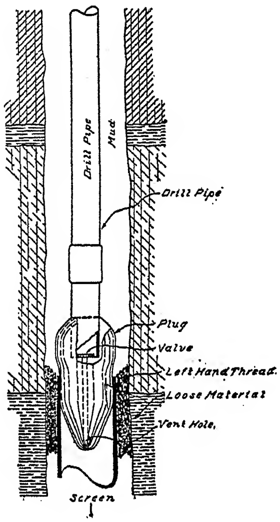

FIG. 9.—TOP OF SCREEN PLUGGED FOR CEMENTING.

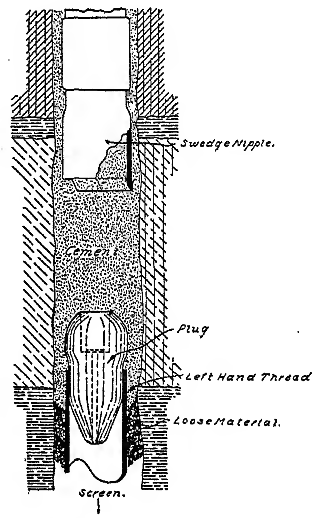

FIG. 10.—SWEDGED NIPPLE WITH LIP.

The cementing operation may be done by the methods already described. After the cement has had time to harden, five days should be plenty, the wooden plugs, brass bars, and back-pressure valve may be drilled out, the inside of the screen washed out with mud down to the wash-pipe plug and the drill pipe then withdrawn. A gate valve should be put on the casing and the well is then ready to bail to test for oil or gas.

Plugging Wells by Cementing

The two-plug cementing system is well adapted to put in a cement plug in the bottom of a well to exclude water or fill a well any distance with cement mortar. For instance, if it is desired to plug off the bottom 20 ft. of a hole the proceeding would be practically the same as cementing in a casing but no by-pass nipple or back-pressure valve would be used and the drill pipe would be employed to pass the cement to the bottom of the hole. The bottom plug should be made 36 in. long, but not tapered, and bored full of holes, which are filled with lead so that the

plug will stay on the bottom. The operation should be so performed that the bottom plug will shut off the pump when it reaches bottom and not by-pass the cement as before described. The drill pipe should then be pulled back until the bottom plug passes out. About half the cement to be placed should be pumped through, then the drilling pipe should be pulled back proportionately.

The top plug and the sack should be used to push the cement ahead and to prevent mixture with the mud following.

In cementing off 20 ft. a surplus of cement mixture should be put in and the drill pipe pulled back only about 22 ft. from bottom and the mud circulation kept on for half an hour to dissipate the surplus cement.

By this method of building up a cement plug from the bottom there need be no time limit to the completion of the cement-plugging operation, as the drill pipe can be pulled back from time to time and cement kept going in until the hole is completely filled. The drill pipe should have a scavenger plug passed through it about every hour to keep it clear of set cement; the joints as disconnected at the top should be washed clear.

Short plugs should be made of neat cement. Larger ones may be cement-and-sand mixtures.

Difficulty of Getting Reliable Information

For instance, the catalogue of hydraulic rotary well-drilling machinery of a prominent oil-well supply company has an article on "Cementing Casing in Wells." I quote from it as follows: "Seventh: Force the plug into the well by running in the drill pipe on top of same until the plugs and cement reach the bottom of the hole; water should be run into the hole as the drill pipe is lowered."

This might be practical for shallow strings of casing up to 800 ft. But how about 2,000 ft.? If the drill pipe is stacked in trebles in the derrick it takes quick work to run in 1,000 ft. per hour, so, if it took an hour to mix the cement and get it in the top of the hole and two hours to run the plugs it would take close to three hours to get the cement to the bottom of 2,000 ft. of casing, when it would probably have set some—enough to be too hard to allow of its being forced up outside the casing into place. But why use a drill pipe for such purpose when the cement can be pumped down 2,000 ft. by the mud-pump pressure in 10 min. or less?

Quoting the same catalogue further: "Ninth: When in doubt of the plugs being together, a measuring line should be used for verification."

As a practical matter the length of the drill pipe is known by actual measurements so that the exact location of the plugs should be known when a drill pipe is run in as directed under the seventh item, so what verification is necessary with a measuring line?

Quoting further: "Eleventh: Cement will not set in oil. . . . ."

Dry cement will not set if mixed with oil because there is no water to hydrate it. Cement properly mixed with water and poured into oil will set and harden in the oil, as I know by actual trial. It would be presumed that the well-supply houses would give clear and exact information in special articles in their catalogues relating to well work; but they are manufacturers and dealers and not experts on well operations.

Water Supply Paper No. 257, *U. S. Geological Survey,* on Well-Drilling Methods, in describing the hydraulic rotary method under "Drilling Operations," p. 71, says: "Drilling is accomplished by rotating the entire string of casing, on whose lower end is a toothed cutting shoe."

It would be practically impossible to drill a well 1,000 ft. in depth with a toothed cutting shoe on a string of casing in any possible formation. A casing that is to be set either as a water-excluding string or as an oil or gas string is never used to drill with. It is true very pretty pictures have for years past appeared in various well-supply dealers' catalogues showing how wells are drilled with rotary shoes, but as a practical matter wells are never drilled in this way. A rotary shoe is a very useful tool to run in with a joint of casing on a drill pipe to take lumps out of a hole and straighten it preparatory to casing. A rotary toothed cutter is sometimes used in core drilling, but the kind of rock or other material it will work in and produce a core from is very limited.

From "Special Operations," p. 74, I quote: "In penetrating firm material it is sometimes necessary to employ a rotary drill bit instead of a rotary shoe. Two styles of bit for this purpose are in general use—the diamond-shaped and the fishtail. The diamond-shaped is usually first employed, and the fishtail afterward used for reaming or enlarging the hole."

Now, this is all wrong. I will venture to say that 99 per cent. of all rotary drilling is done with a fishtail bit. The Sharp & Hughes bit is used for rotating on hard rock.

But why drill a hole too small and then ream it down? What is gained? As a matter of fact it usually takes longer to ream 100 ft. of hole than it would to drill the same 100 ft. of the full-sized hole at the first operation. Skillful rotary drilling completes the hole to the full size required and "muds up" all at one operation.

Technical Paper No. 32, *Bureau of Mines,* on Cementing Process of Excluding Water from Oil Wells as Practised in California, gives under "Recommendations and Suggestions," p. 7, the following: "3. The well should be cleared of all débris and mud and enough clear water should be pumped in to wash out any sulphur or alkaline water."

To pump clear water into any well at any time before its completion is a questionable proceeding, even if drilled with the cable tools in a

hard formation. In wells drilled in unconsolidated formations with the rotary such action would mean complete destruction of the well. Only after all cementing is done and the well is completed and fully protected by casing or screens is washing with clear water practicable.

Quoting again from the same source: "5. Previous to cementing, some definite information should be gained relative to the action of the water in the hole on the setting qualities of the cement."

I regard it as not to the point to talk about the action of salt, alkaline, sulphur, or gypseous water or oil in the hole on cement when the neat Portland cement is first hydrated with suitable water, mixed on the surface, and passed with practically no chance of serious contamination to its final place.

Quoting again from the same: "An excess of gypsum in the water might delay the setting of ordinary cement three or four months."

I would be glad to be "shown" on a statement of this kind. Experiments of E. Candlot, an eminent cement expert (*Sibley Journal of Engineering*, January, 1905), show that when gypsum was ground with cement clinker in the ratio of 1½ parts in 100, which proportion was found to produce the best effect in retarding the set, the maximum time for initial set was 5 hr., and final set 19 hr., and not three or four months.

Technical Paper No. 42, *Bureau of Mines*, on p. 6, describing a blow-out preventer, says: "The preventer, when used, is always placed on the last string of casing set or landed, thus controlling the flow between that string and the drill pipe or casing that is being lowered." Then, same page, under "Sealing of Artesian Water or Gas Strata" says, "This end can be easily accomplished in drilling with a rotary rig by forcing muddy water to the bottom of the well through one of the lateral openings of the preventer."

Suppose, for instance, the preventer casing was set at 700 ft. and the drill was working at 1,000 ft., leaving 300 ft. of hole open. It would be a practical impossibility to mud the bottom of the hole by pumping muddy water into the top of the well between the casing and drill pipe.

It is an elementary requirement in rotary drilling and mudding to have a mud circulation down the drill pipe, or a casing, and up between this pipe or casing and the walls of the well, if any mudding is to be accomplished.

The wobble of the rotary-drill stem must do the plastering; it cannot be efficiently done in any other way. Under the same head comes a most surprising statement: "The mud can easily be removed by releasing the pressure or bailing down the water in the hole."

But it is not necessary to quote more. The educated engineer that desires some information on well drilling and operating cannot possibly study out how mudding and cementing is really done from such a report. In marked contrast one can find in the Institute *Transactions* exact,

clear, and authoritative information on drilling holes in prospecting for coal, also on mining and preparation of coal for market, furnished by men who have actually performed the work. Unfortunately, petroleum mining has not had like information on drilling wells, and on refining and marketing the oil.

There were over 25,000 wells drilled for oil and gas in the United States east of the Rocky mountains the past year, or a well completed every 21 min. Their average cost was probably between $2,500 and $3,000 each, or between $50,000,000 and $75,000,000 was expended in drilling to keep up the supply of oil and gas.

It is really surprising that no more has been written upon the art of drilling wells and producing oil and gas by men experienced in these matters.

The recent formation of a technical committee on Petroleum and Gas by the American Institute of Mining Engineers comes at an opportune time, and I trust that this action will bring out in the future as valuable and accurate information on petroleum mining as the Institute has in the past published on coal mining.

Discussion

Arthur Knapp, Ardmore, Pa. (communication to the Secretary*).—*Cementing Short Strings of Large-Sized Casing.*—The necessary fittings, such as back-pressure valves, nipples, by-passes, etc., for 12½-in., 15-in., or larger size casings are very expensive. These strings are seldom more than 500 ft. long, and cementing may be safely accomplished as follows (see Fig. 11):

First Plug.—This is a cylindrical wooden plug with a length about twice the diameter. A hole whose diameter is one-third that of the plug is bored through the plug. The bottom of this plug is fitted with a circular piece of belting the same diameter as the casing. This belting is so cut as to form a flap valve over the lower end of the bored hole in the plug.

Second Plug.—This plug is a cylinder with a length about twice the diameter, and the customary belting is nailed on its lower end.

Lugs.—Four brass lugs about ¾ in. in diameter are inserted in the casing shoe in such a manner as to project into the casing about 1½ in.

Operation.—The flap valve on the first plug is held shut by several small nails. After mud circulation is established around the casing this plug is inserted and the cement pumped in on top of it. The second plug is then put in on top of the cement and the pump again started. When the first plug reaches the brass lugs inserted in the shoe (see Fig. 11)

* Received Jan. 29, 1914.

it can go no further. The pump pressure then opens the valve and forces the cement through the plug and into position outside of the casing. When the second plug reaches the first plug the pump pressure immediately increases, showing the cement to be in place. The casing is then lowered to bottom and cementing has been accomplished. It is good

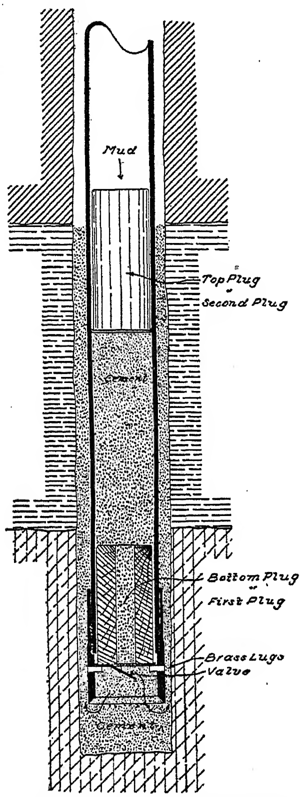

FIG. 11.—CEMENTING LARGE-SIZED CASING.

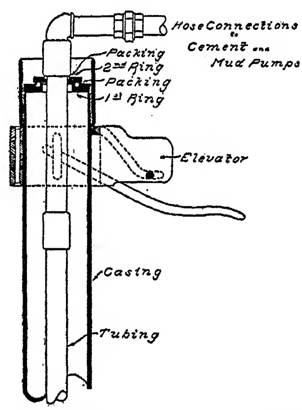

FIG. 12.—TOP CASING COLLAR.

practice to leave the pump pressure on the casing for some time to prevent any back flow, should there be a leak around the shoe.

Cementing Very Long Strings of Casing.—The use of tubing ($2\frac{1}{2}$ to 4 in.) to pump cement through in setting long strings is good practice. The contamination with mud which is liable to occur in the larger casing is materially reduced in the tubing. The total inside surface of 2,500 ft. of 8-in. casing is 5,250 sq. ft., and of 3-in. tubing 2,000 sq. ft., the ratio being as their respective diameters.

Fig. 12 shows the top casing collar. A steel (never cast-iron) ring is screwed into this collar, with a hole through it large enough to pass a tubing collar. A second ring is fitted to a tubing nipple with packing inserted to pack against the tubing collar. Packing is inserted into the

first ring and on it the second ring sets, thus effectually sealing the top of the casing and preventing back flow inside of the casing.

Fig. 13 shows the bottom of the tubing and casing. The tubing is fitted with a collar into which is screwed a bushing. Two holes are drilled into the tubing far enough above the collar so that when the bottom plug hits the bushing there will be just space for the cement to pass out above it. This figure shows the top plug at the instant before it reaches the bottom plug and shuts down the pump, thus indicating that all of the cement has passed from the tubing. When the cement has all been pumped into place the casing is lowered to bottom and cementing

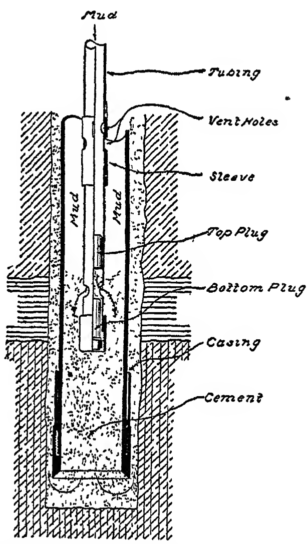

FIG. 13.—BOTTOM OF TUBING AND CASING.

has been completed. The tubing is now plugged at the bottom and if pulled would be full of mud. It is often pulled this way. Fig. 3 also shows a sleeve which may be used to vent the tubing by setting the string on bottom and allow the string to be pulled dry.

After the casing is on bottom the hose connections are removed and a longer nipple is screwed into the top of the tubing. The string of tubing is then lowered to bottom. This causes the sleeve to slip up on the tubing and bring the vent holes into line. If now the hose connections are again screwed on, the cement left in the bottom of the casing may be pumped out. This leaves a minimum of cement to be drilled out after the casing is set and is an advantage over the method of using full-sized plugs. With this method of using tubing there is no danger that an accident to the cement pump will leave the cement where it will set in the casing or tubing. The vent at the bottom of the tubing will allow the circulation of mud to wash superfluous cement from the well.

O. P. Hood, Pittsburg, Pa.—In the rotary system of drilling the circulating mud performs several functions. It removes the cuttings from the path of the bit and gives a clean surface for the bit to work upon, it brings the cuttings to the surface where they can be examined, it may plaster the wall of the hole and also penetrate some of the formations.

Mr. Knapp calls special attention to the plastering effect, but seemingly overlooks the matter of penetration into porous formations. If mudding a well refers to plastering the wall of the hole, as implied in the criticism of *Bureau of Mines Technical Paper* 42, then a circulation is indeed necessary to distribute the mud thickened by the cuttings along the length of the hole. There is, however, an action of muddy water quite apart from plastering the walls of the well and which does not depend upon circulation. A fluid may flow from a formation into a bore hole because of a reduced pressure at the hole, but the direction of this flow can be reversed by creating a fluid pressure in the hole greater than that in the formation. The amount of radial flow will depend upon the pressure difference, the porosity of the formation, and the viscosity of the fluid. A muddy fluid of such character that fine clay will stay in suspension will finally clog the small and tortuous passages by deep penetration laterally into the formation.

Maintaining a sufficiently high static pressure on a column of muddy fluid, even without circulation, will therefore produce an effect in closing a formation. By releasing the pressure sufficiently the passages can again be cleaned by the superior pressure within the formation. This action is independent of any plastering of the surface and of any wobbling of the drill pipe.

The use of mud fluid dates back to at least 1889, but has been restricted to such conditions as described by Mr. Knapp, where it was believed fundamental that such mud should circulate down the drill pipe, up the walls of the well, and overflow to a mud pit at the surface. Reliance on the radial flow of the mud, and particularly as applied to the dry hole method of cable-tool drilling, is believed to be recent and has had numerous successful applications in the Oklahoma field.

Ralph Arnold and V. R. Garfias, Los Angeles, Cal. (communication to the Secretary*).—Under the heading "Difficulty of Getting Reliable Information," Mr. Knapp makes the following criticisms on *Technical Paper No.* 32, *Bureau of Mines*, Cementing Process of Excluding Water as Practised in California, by ourselves. He first takes exception to the following recommendation made by us for the accomplishment of a successful cementing operation:

"The well should be cleaned of all débris and mud, and enough clear water should be pumped in to wash out any sulphur or alkaline water."

* Received May 4, 1914.

We do not know what is considered good practice in Pennsylvania, but the above recommendation seems to be warranted in California and is followed generally by up-to-date cementers here; at all events, if Mr. Knapp is correct, we err in common with many well-posted California operators. In corroboration of this and for ease of reference, we will quote only from the very interesting paper by F. W. Oatman[1] presented before the Institute at the same time as the paper here discussed.

"The water string is raised a foot or so from bottom and water pumped down inside the casing and up to the surface around the outside of the casing. The purpose of this is: To assure the operator that there is free circulation; to wash away the mud, oil, etc., from the sides of the casing and the hole, so that cement may adhere thereto; to open the space around the casing so that a complete ring of cement may form. This water circulation may be continued for a considerable period, *sometimes as much as* 30 *hr. or more,* to clean the hole thoroughly."

Of course, one readily can imagine a combination of unusual conditions which might render the pumping of clear water always injurious, and perhaps such prevail in Pennsylvania, but one should not lose sight of the fact, as indicated by the title of our paper, that the information contained therein applies only to California.

Mr. Knapp also takes exception to that part of our fifth recommendation reading as follows:

"Previous to cementing, some definite information should be gained relative to the action of the water in the hole on the setting qualities of the cement,"

and he regards as "not to the point to talk about the action of salt, alkaline, sulphur, or gypseous water or oil in the hole on cement . . . " The writers fully agree with Mr. Knapp upon the uselessness of only talking about these matters but they strongly favor the advisability of gaining some definite information as to the action on the cement of the water in the well.

Again quoting from the instructive paper of Mr. Oatman, p. 638:

"Considerable experimental work has been done by many investigators to determine the effect of various salts on rate of setting. Calcium chloride, $CaCl_2$, decreases time of set, and if over 2 per cent. by weight is used is likely to so hasten the set as to make the cement difficult to handle. The use of ½ per cent. of sal soda, Na_2CO_3, has been found effective in hastening the set in wells troubled with gas.

"Since hot water is encountered in many oil fields, its effect on cement is worthy of notice. In general it may be stated that the time of setting decreases with increasing temperature."

If the physical and chemical properties of the water in certain cases, however few, affect the behavior of cement, as noted by Mr. Oatman, it is obviously important to ascertain these facts before cementing, particu-

[1] Water Intrusion and Methods of Prevention in California Oil Fields, this volume, p. 627.

larly when such an investigation usually requires little expenditure of time and money.

Mr. Knapp also objects to the following from the same paragraph:

"An excess of gypsum in the water might delay the setting of ordinary cement three or four months."

The statement as made is correct, for an excess of gypsum in the water *did delay* the setting of ordinary cement three or four months, as explained below by Prof. C. W. Wing, head of structural engineering at Leland Stanford, Jr., University, in a letter to the junior author:

"In the basement of the Royal Insurance Building in San Francisco some difficulty with the setting of the cement was experienced. This basement was some six or eight feet in places below the ground water lines. . . The floor was a foot or more in thickness, and when the time came for placing the water proofing coating it was found that the concrete in the floor had failed to harden, although at the time I visited it it was more than a month old. In some of the depressions seepage water was standing. In investigating the causes of the slow setting of the concrete it was found that this building was in line with a gypsum spring that used to exist on the hillside above the building. An analysis of the seepage water showed that it contained appreciable quantities of gypsum, and briquette samples of cement stored in this water failed to harden and reach the same strength that identical samples stored in the laboratory gave. . . . . While this hardening had been delayed there was no reason to suppose that in due course of time the concrete would not reach its full strength. . . . . The basement, on my recommendation, was finished as originally designed, and as far as I know has never given any trouble. The effect of the gypsum, therefore, was merely to delay the hardening of the concrete and not to destroy its value. . . . A series of tests with Portland cements *in which the only gypsum is that contained in the water* would determine the effect of gypsum in the water upon the rate of setting of the cement."

It should be noted by the wording of the paragraph in question that this condition was not intended to represent an every-day occurrence, but one which might be repeated, and the writers deemed it advisable to caution operators against such a possibility. We were very glad indeed "to be shown" when Professor Wing brought this to our attention.

Mr. Knapp then takes issue with statements made by us in *Technical Paper No.* 42, published by the Bureau of Mines. As the quoted portions do not convey the complete meaning intended by the writers, we beg to quote in full the paragraphs in question:

"Sealing of Artesian-Water or Gas Strata"

"It sometimes becomes necessary to exclude from the drill hole water or gas found in an overlying sand in order to control the well or to recover or test for the oil below. This end can be easily accomplished in drilling with a rotary rig by forcing muddy water to the bottom of the well through one of the lateral openings of the preventer, the pressure being regulated by closing the valve connected to the other opening. A back-pressure valve in the drill pipe will prevent the flow of the mixture through this

casing. By drilling a short distance and forcing as much mud as possible into the porous sands penetrated, a plastered wall of clay is built throughout the gas-bearing or water-bearing strata. After the entire thickness has been penetrated and the casing landed in an impervious bed, another string may be used to tap the oil sands below. The gas thus excluded can be recovered afterward by drilling shallower wells to the upper sands.

"This method can also be employed in drilling the entire thickness of a gas or oil sand under tremendous pressures, an operation that might otherwise prove troublesome. The mud can easily be removed by releasing the pressure or bailing down the water in the hole, a strainer or perforated casing being placed in the sand to prevent the wall of the well from caving when the pressure is released."

Mr. Knapp's opinion to the contrary notwithstanding, the above description represents actual conditions which have been put into practice by J. A. Pollard and other petroleum engineers.

I. N. Knapp (communication to the Secretary*).—The discussion of Messrs. Arnold and Garfias of my paper on Cementing Oil and Gas Wells has been carefully read to me. Also, I have read F. W. Oatman's paper and I do not think it has been interpreted correctly by them.

They quote Mr. Oatman as washing out the well, presumably with *clear water*, "to open the space around the casing so that a complete ring of cement may form." No one can by any practical means direct the action of the clear water so that it will produce this ideal condition, which must be approached to successfully cement in well casing. Clear water by its solvent, erosive, and undirected action will tend to wash away the walls of the well at points of least resistance and work away from the ideal condition.

My paper explains in detail how to bring a well into condition for cementing, so I will not repeat. If Mr. Oatman is working in territory where the walls of a well will stand 30 hr. washing with water, he is to be congratulated on not having difficult territory to handle. He is again quoted as to experimental work to determine the effect of various salts, and troubles with gas, oil, and hot water in cementing wells.

As I have shown in my paper, all ground water, oil, and gas may and should be excluded from a well before cementing, so it is not necessary to consider their action on cement unless the driller deliberately elects to let them bother him.

Now as to hot water. I did not discuss this in my paper, but I have drilled into a water-bearing horizon of a known temperature of 99° F. with the rotary, using a mud circulation. This mud, as coming from the well until drilling stopped, did not exceed 72° F. as noted by a standarized thermometer. There would have been ample time to have cemented without much increase in this temperature. This was clearly shown by the fact that when the well was bailed and the hot water warmed up the

* Received May 14, 1914.

casing it expanded fully 10 in. in 1,880 ft. Thus hot-water conditions admit of easy control.

The quotation from Prof. C. W. Wing's letter does not distinguish between "setting" and "hardening" of cement or concrete. It is not made clear that the gypsum spring was the cause of the concrete failing to harden, as the same result might have been produced in other ways. I would refer to my paper (p. 651) as to the difference between "setting" and "hardening" of cement. I still object and desire "to be shown" that:

"An excess of gypsum in the water might delay the setting of ordinary cement three or four months."

Let us not forget the main point, as yet uncontroverted, that all ground water, gas, and oil may and should be excluded from a well before cementing.

The Killing of the Burning Gas Well in the Caddo Oil Field, Louisiana

BY C. D. KEEN, SHREVEPORT, LA.

(New York Meeting, February, 1914)

IN the latter part of the summer of 1913 the Conservation Commission of the State of Louisiana, under presidency of M. L. Alexander, decided to stop the waste of natural gas going on at the "burning gas-well," located about $\frac{3}{4}$ mile southeast of Oil City, La. On several occasions, both in newspapers and in reports, comment had been made on the condition of this well, its harmful effect on the Caddo gas field, and the considerable loss, estimated at several thousand dollars each month, caused by the escape of the valuable fuel. But nothing had been done to bring the well under control and prevent further waste of gas until the State Conservation Commission took the matter in hand.

The gas fields of Louisiana are among the greatest in the country. So far most of the gas has been found in the Caddo field proper, although considerable development has been done in and around the city of Shreveport and near the town of Mansfield in DeSoto parish. To extend the life of the gas fields and to prevent the quick exhaustion of the supply of the natural fuel are matters of vital importance for this section of the country.

Four gas companies have entered the Caddo field and supply the surrounding towns and cities with gas. The Arkansas Natural Gas Co. has pipe lines to Little Rock, Ark., and supplies gas to the following cities and towns in that State: Texarkana, Hope, Garland, Emmet, Prescott, Boughton, Beirne, Gurdon, Arkadelphia, Gum Springs, Malvern, Donaldson, Gifford, Perla, Beaton, Beauxite, Mabelvale, Bryant, Sheridan, Pine Bluff, Little Rock, Argenta, Pulaski Heights, and Hot Springs. The Southwestern Gas & Electric Co. transports gas to Mooringsport, Blanchard, Caddo, Rodessa, Oil City, Vivian, Bloomburg, Hosston, Ida, Dixie, Belcher, and Shreveport. The Marshall Gas Co. supplies gas to the town of Marshall, Texas. The Louisiana Co. has a line to Shreveport.

In the oil field the gas is used for drilling purposes, and the operators either have their own gas system or buy from the gas companies. At the present time the surrounding territory depends for its fuel supply on the Caddo field, and the importance of the conservation of the natural-gas

resources of the State was fully appreciated by the Commission, when it ordered the killing of the "wild well."

The object of the present paper is to give an account of the effective method by which the Commission, represented by its Agent, J. W. Smith, brought the well under control, by drilling a relief well to the

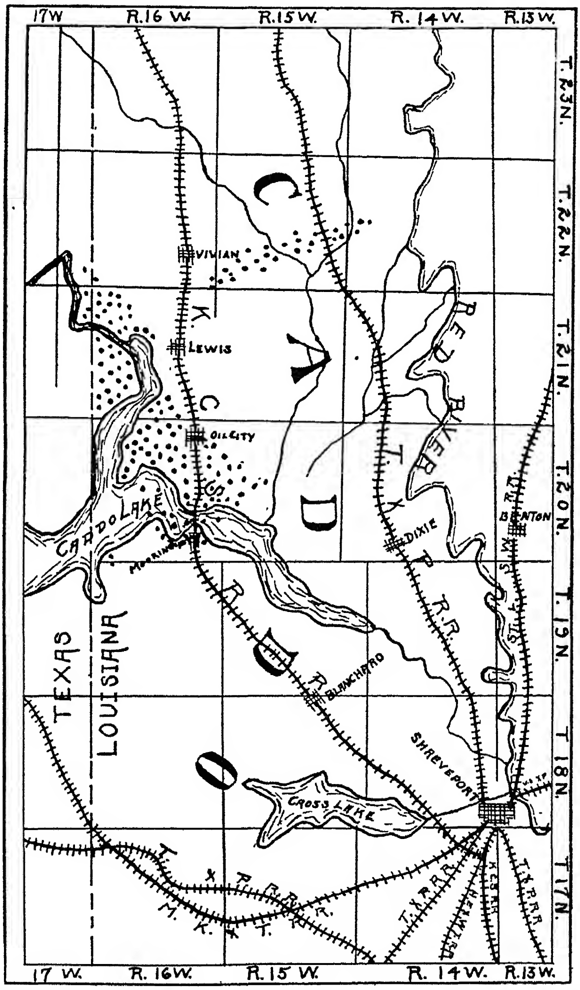

FIG. 1.—SKETCH MAP OF THE CADDO OIL FIELD, CADDO PARISH, LA.

stratum from which the well was blowing out and forcing water under high pressure through the bore hole into the gas sand.

It may be useful to give a short sketch of the geological occurrence of oil and gas in the Caddo field. Those interested in the subject are referred to *Bulletin No.* 429, *U. S. Geological Survey* (Oil and Gas in Louisiana, by G. D. Harris), for a complete description of the field.

Location

The oil and gas field is located in Caddo parish, in the northwestern part of the State of Louisiana, about 20 miles north of the city of Shreveport, as shown in Fig. 1. The field proper begins at the town of Mooringsport and extends in a direction west of north for about 12 miles, the width of the field ranging from 6 to 8 miles.

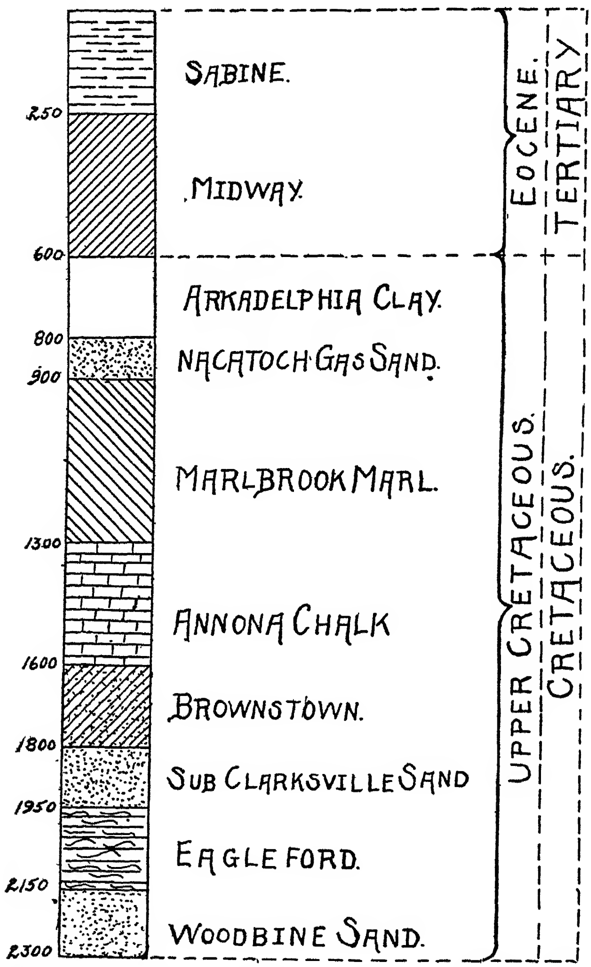

FIG. 2.—LOG AND SECTION OF A CADDO WELL.

Occurrence of Oil and Gas in the Caddo Field

The strata encountered by the drill in the Caddo field belong to the Lower Tertiary and Upper Cretaceous. They consist mostly of soft shales, marls, and clays, with the exception of the Nacatoch sand, the

Annona chalk, the Sub-Clarksville sand, and the Woodbine sand. Fig. 2 is a general section of the strata.

Nacatoch Sand.—The Nacatoch sand is encountered at a depth ranging from 750 to 850 ft. from the surface, according to local topography and stratigraphy. The upper part of the formation is developed as a close, hard quartzite, the thickness of which varies from 8 to 10 ft. The quartzite is an excellent cap rock for the gas, found in the sand below. The gas formation is a close, fine-grained sandstone or a packed sand, the thickness of which seldom exceeds 20 ft.

Directly under the gas sand, still in the Nacatoch formation, the drill strikes sand beds which contain salt water. Great precaution has to be exercised not to drill a gas well into salt water and it is not advisable to enter more than 8 or 10 ft. in the gas formation. The total thickness of the formation may be estimated at 100 ft.

In that part of the field known as the Shallow Territory, lying east of the town of Vivian (see Fig. 1), the Nacatoch sand yields a heavy fuel oil.

When the Caddo oil field was first discovered the gas from the Nacatoch sand gave the drillers considerable trouble on account of the high rock pressure, which at the time was 450 lb. to the inch. On several occasions the drilling mud was blown out by the gas and the wells could only be kept under control with great difficulty. The rock pressure quickly declined, however, partly because of the enormous quantities of gas used for commercial purposes, partly on account of a great volume of the fuel going to waste. At the present time the rock pressure of the Nacatoch gas sand does not exceed 100 lb. to the inch.

Sub-Clarksville Sand.—The Sub-Clarksville sand is the second gas horizon in the field. It is encountered at a depth ranging from 1,800 to 1,900 ft. Its structure is almost identical with that of the Nacatoch sand. It has shown gas under high pressure in several wells, but so far the Nacatoch sand furnishes practically all the gas now being used from the Caddo field. Like the Nacatoch sand, the bottom of the formation contains salt water in great quantities. Its total thickness varies from 75 to 150 ft.

Woodbine Sand.—This is the horizon from which the bulk of the oil in the Caddo field is obtained. It is overlain by the Eagleford shales. There are no sharp lines of division between the two formations. At a depth of about 2,150 to 2,200 ft. the Eagleford shales become more sandy and change gradually into the Woodbine. The Woodbine is developed in Caddo as a series of interstratified sands and shales; the horizontal as well as the vertical distribution of the sand in the shale is very irregular, caused by the thinning out of the sand lenses and the grading into sandy shale and shale. It is a typical shallow-water deposit, the sudden changes in structure being caused by changing tides, winds, and

currents. It is in these sands that the big oil wells, for which the Caddo field is famous, are struck. In the bottom of the Woodbine, under the oil-bearing sands, salt water is encountered, as in the gas sands.

Annona Chalk.—Mention must be made of the occurrence of oil in places in the Annona chalk. The "chalk rock" is struck at about 1,300 ft. and has a thickness of 300 to 350 ft. The occurrence of this oil is not sufficiently explained. From the data at hand it seems that the oil fills crevices which have been caused by slight faulting.

History of the "Burning Well"

The well is situated in the SE. ¼ of the NE. ¼ of the SW. ¼ of Section 7, T. 20 N., R. 15 W., on a 10-acre tract owned by B. G. Dawes,

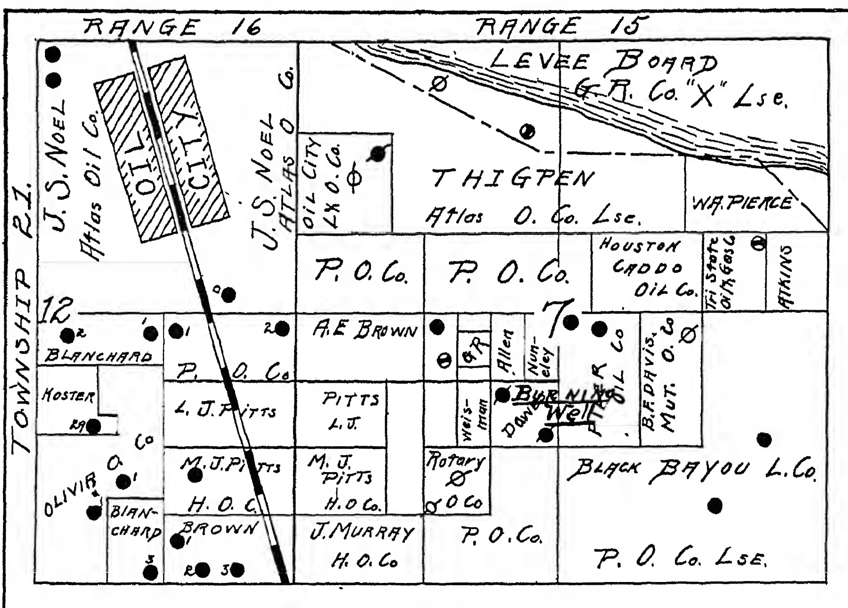

FIG. 3.—MAP SHOWING THE LOCATION OF THE BURNING WELL.

Trustee. Fig. 3 is a map of the region. Work on the well was started on Mar. 17, 1908. On May 11, 1908, the drillers had reached a depth of 2,065 ft. The well was cased off with 300 ft. of 10-in. casing pipe and 900 ft. of 8¼-in. casing pipe. The 6-in. casing pipe was not set yet. During the day the well began to give trouble and blew out from the 1,800-ft. gas stratum (Sub-Clarksville sand). The drilling mud was made as heavy as possible and the driller started to pull the 4-in. drill pipe out of the hole to change the drill bit. In the night during a heavy rainstorm, while the 4-in. drill pipe was being put back and was

about 350 ft. from the bottom, the well blew the drilling mud out again with much more violence than before. The gas pressure raised the drill pipe up, which unlatched the elevators, and the drill pipe dropped 350 ft. in the bore hole.

The well continued to blow out, increasing all the time in volume, which was estimated the next day at 40,000,000 cu. ft. in 24 hr. The well also made a strong salt-water flow. The owners of the well did everything in their power to get the well under control. A lubricator[1] was made of two pieces of $8\frac{1}{4}$-in. pipe and screwed on the $8\frac{1}{4}$-in. casing to kill the well, but as soon as the valves were closed the gas broke the seats of the $8\frac{1}{4}$-in. and 10-in. casings and began to blow out under the derrick floor. The valves on the lubricator had to be opened up again, to release the pressure from the casing, but the flow of gas around the $8\frac{1}{4}$-in. casing had relieved the pressure of the drilling mud on the 800-ft. gas, which now started to blow out between the 10-in. and the $8\frac{1}{4}$-in. casings.

On the evening of May 13 a cyclone completely destroyed the derrick and drilling rig. A deep hole was dug around the 10-in. casing, with the well open, flowing gas and salt water, with the object of putting a cement block around it, which might hold the gas back long enough to lubricate the well. At 20 ft from the top a split was found in the 10-in. casing pipe. After several days the drillers succeeded in getting a joint of 14-in. pipe over the 10-in. pipe and the two were cemented together, and a big block of solid cement was placed around the casing. The cement was allowed several days to harden, while the well was blowing gas and salt water. Then a second attempt was made to lubricate, but the pressure was so strong that the gas escaped outside the 10-in. casing into the shallow-water sand, which is found at about 75 ft. in that part of the field, and blew out on the ground about 300 ft. away from the well. The well had to be opened up again and all the material brought in safely and a last attempt made to kill the blowout. But the gas continued to escape around the well, coming closer and closer to the hole. The owners

[1] A well is killed with a lubricator in the following manner: Two lengths of pipe, with gate valves at the top and bottom, are screwed on the casing of the well, the lower valve is closed and the two pieces of pipe filled with heavy mud. Then the upper valve is closed and the lower valve opened. The pressure in the well and in the lubricator becomes equal and the mud drops through the lower valve into the well. The lower valve is closed and the upper valve opened again and the operation is repeated until the bore hole is filled to the top with heavy mud and the blowout stopped. The operation of lubricating takes considerable time, and nowadays a better method is used. The well is directly connected up with a line pump, that can put up a pressure of 700 or 800 lb. to the inch. Then the well is closed in and the pressure in the well runs up to the rock pressure; but the pump is able to work against that pressure, and the bore hole is filled with mud in a much shorter time than with the lubricator.

then abandoned the well, considering it impossible to get it under control. In less than three weeks' time the escaping gas and water had formed a crater around the well at least 100 ft. in diameter, which the waves made larger and deeper as the time passed.

In June, 1908, the well was put on fire because the gas was a continuous danger to those who had to work and live in the surrounding woods. The well stopped burning in Feburary, 1909, but caught fire again soon afterward. The well was allowed to run wild until the summer of 1913. Most of the time the gas was burning, but heavy rainstorms and wind would put it out. After a few days the gas would catch fire again. The muddy waves caused by the escaping gas kept on washing more and more material in the hole, thus increasing the size and depth of the crater, until finally they had formed a circular pool 225 ft. in diameter, in the center of which the escaping gas threw up a body of mud 25 or 30 ft. high.

The volume of the gas escaping from the well at the end of its life was estimated by experts to be between 8,000,000 and 10,000,000 ft. per day. Not only was this waste of gas deplorable, the value of which, at about $2\frac{1}{2}$ c. per 1,000 cu. ft. at the well, amounted to about $250 per day, but also the well affected the rock pressure of the surrounding territory, which had fallen below 100 lb. to the inch, and allowed the salt water which occurs in the bottom of the Nacatoch sand to enter the gas formation.

Killing of the Well

When the Conservation Commission took the matter in hand it was decided to first empty the pool which the blowout had made, to find out the condition of the casings. It took about 20 days to empty the crater. The shape of the crater is shown in Fig. 4. The bottom of the pool sloped from the border for about 50 ft. until it reached a depth of about 10 ft. below the surface. From there the crater had a conical shape, with a diameter of about 125 ft. sloping down to the old bore hole, where it had a depth of from 37 to 40 ft. The top of the 10-in. and the $8\frac{1}{4}$-in. casings could be seen in the bottom of the crater. The well was not blowing outside the 10-in. casing pipe. Evidently after the pressure of the well had gone down, the caving mud had fallen in around the 10-in. casing so that the water and gas could only escape between the 10-in. and $8\frac{1}{4}$-in. casings. It was observed that the well blew out cold salt water, which showed from what depth the blowout was taking place, because the salt water found in the deep sand rock is warm, whereas the water from the Nacatoch sand has a much lower temperature.

The tops of both casings were worn very thin and it was impossible to screw any connections on to them. The original plan was to set a

disk wall packer inside the $8\frac{1}{4}$-in. casing on 4-in. pipe about 100 ft. from the top and let the well blow through the 4-in. pipe, then pack the space between the $8\frac{1}{4}$-in. and the 10-in. casings with a stuffing-box casing head and make a cement block outside the 10-in. casing, after which the well perhaps could be closed in. But the condition of the top of the casings would not allow this scheme to be carried out. Then it was de-

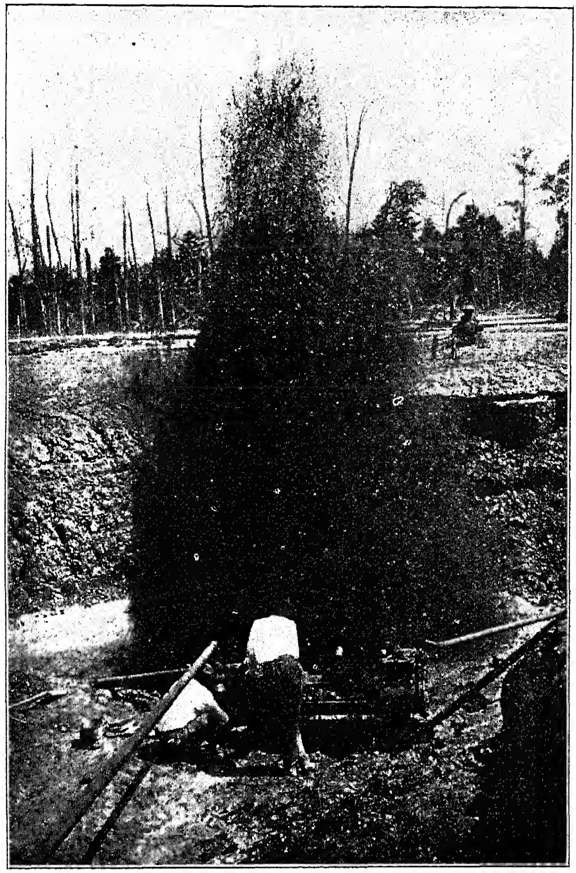

FIG. 4.—VIEW OF CRATER OF BURNING WELL AFTER BEING PUMPED DRY.

cided to drill a well, which was called a "relief well," as close to the old hole as was possible under the circumstances, and to try to stop the flow of gas and water by pumping water or mud in the gas formation. The contract for drilling the well was let to W. W. Blocker.

When the pumps were moved the crater filled up with the salt water thrown out by the well.

This relief well was drilled on the southeastern side of the crater, at a distance of 125 ft. from the center, as shown in Fig. 5. The hole was

cased off with 211 ft. of 10-in. casing and 792 ft. 11 in. of 8-in. casing pipe, both cemented. The 8-in. casing pipe was set on the top of the Nacatoch sand. The cement was allowed to harden for nine days, after which the seat of the 8-in. casing was tested. Mr. Smith ordered

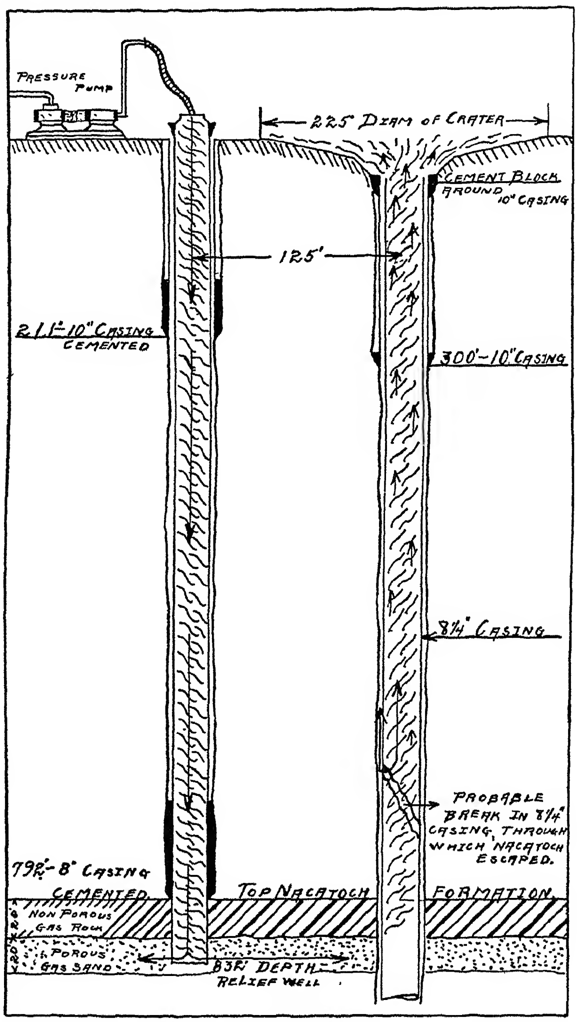

Fig. 5.—Section through Burning Well and Relief Well.

the well to be drilled with clear water 20 ft. in the Nacatoch formation. The rock encountered in this 20 ft. was not porous enough, in the judgment of Mr. Smith, to attempt to pump in water. The well was then drilled 20 ft. deeper in the same formation, the total depth being 832 ft.

The formation found in the last 20 ft. was a coarse sand rock, considerably more porous than the first 20 ft. below the 8-in. casing. It was

decided to make the experiment at this depth. A reservoir covering 3 acres of land, ranging in depth from 6 in. to 3 ft., was filled with water, and the 8-in. casing was connected with the pump and the full pressure put on the formation.

The pump used was an ordinary 10 by 6 by 12 in. rotary drilling pump; the boiler pressure was 120 lb. per inch and the pressure put up by the pump as registered by the gauge was 310 lb. per inch. After the hole was filled, the pump ran at about 5 rev. per minute for 1 hr., corresponding to a volume of about 29 gal. per minute being forced into the gas formation. During the next 5 hr. the number of revolutions increased slowly from 5 to 10 per minute, but the gauge registered the same pressure. During the following days the full pump pressure was left continually on the well, the number of revolutions increasing gradually and the pressure against which the pump had to work decreasing. After the fifth day the pressure registered on the gauge was about 150 lb. to the inch and the number of revolutions 30 per minute, which was equivalent to a volume of 165 gal. being forced into the gas sand each minute.

On the seventh day the pressure was 50 lb. to the inch and the pump was running at the rate of 42 rev. per minute. It was noticed that the pressure would fall considerably for a short time and then run up again to where it had been previously, which can only be explained on the hypothesis that the water opened up a new channel in the formation, thus relieving the pressure, and when the cavity was filled the pressure went up again to the point where it had been before. From the seventh day on a slow decrease in the strength of the eruptions was noticeable, and on the tenth day the eruptions ceased. At the moment the eruptions stopped the salt water and mud in the pool flowed back in the old bore hole, leaving the crater entirely empty.

Although there was no gas escaping from the hole, the pumping was continued for three more days, to drive the gas still further back in the formation and away from the well.

The space between the 8¼-in. and the 10-in. casings was filled with cement and a heavy cement block was put around the 10-in. casing. Then several blasts of dynamite were fired around the circumference of the crater about 10 ft. apart. The explosion caused several tons of shale and clay to fall to the bottom of the crater. If the well should start to flow gas and salt water again, the salt water would mix with this shale and clay and make a thick mud, which would kill the well.

Although the blowout was killed successfully, and the possibility that the well will give trouble again is very small, the derrick and casing were not removed from the "relief well," as a further precaution, so that work can be started at a moment's notice to pump water in the gas sand and cut off the flow of gas.

Value of Gas Wasted and Conserved

A low estimate of the average production of the well during the five years that it ran wild puts it at 15,000,000 cu. ft. per day. The volume of natural gas which escaped into the atmosphere during this time would be 27,000,000,000 cu. ft. At $2\frac{1}{2}$ c. per 1,000 cu. ft., this volume of gas represents a value of $675,000.

In the town of Shreveport the selling rate for manufacturing gas is $7\frac{7}{10}$c. per 1,000 cu. ft. If all the gas which went to waste at the burning gas well had been sold in the city of Shreveport for manufacturing purposes only, it would have brought in $2,079,000.

At the time the well was killed the eruptions were still very violent and during the last year no decrease in their strength had been noticeable. No doubt it would have been several years before the burning well would have died a natural death. It is impossible to estimate the value of the gas that has been saved by the energy and activity of the Conservation Commission, but from the above figures it can be seen that it must amount to several hundred thousand dollars.

The cost of drilling the "relief well" and putting out the burning well was approximately $6,000, which is a very small amount compared with the value of the gas saved.

Chlorides in Oil-Field Waters

BY C. W. WASHBURNE, WASHINGTON, D. C.

(New York Meeting, February, 1914)

The waters of many oil fields have been regarded as buried sea water which has been retained in the sediments since the time of their deposition. The preservation of connate water through geological time has seemed improbable to only a few geologists, but there is room for doubt that buried sea water could remain in the strata during their periods of deformation and during the many subsequent epochs of the circulation of meteoric ground-water. Some have even suggested that the calcium chloride water in the deep mines of the Lake Superior region is ancient sea water buried in the Algonkian lavas, but it is hard to understand how such water could be derived from the highly sodic and sulphatic water of the sea. It would seem more plausible to connect the calcium chloride with the highly calcic magmas of the greenstones in which it is found.

Chemical analyses of waters associated with oil differ widely from the composition of sea water, requiring extensive alteration of the latter, if the former is truly its derivative. The first notable difference is the general absence of sulphates from oil-field waters, but this has been explained satisfactorily through reduction by hydrocarbons and organic matter. Oil reduces sulphates with the production of hydrogen sulphide (or sulphur), water, and carbonates (or carbon dioxide).

The second striking difference is in the high ratio of chlorine to sodium. An examination of the analyses of chloride waters from oil fields shows that they contain a large relative excess of chlorine over that in sea water. Moreover, there is difficulty in finding chemical reactions that are probable in nature, by which sea water could be converted into anything like the chloride waters of oil fields. In the latter a large part of the chlorine occurs as calcium and magnesium chloride. This condition might be produced by the removal of sodium carbonate, which, however, cannot be precipitated in the presence of much calcium or magnesium.

Composition of Chloride Waters from Oil Fields

	Sea Water	Pennsylvania		Kansas	
	A	B	C	D	E
Cl	55.29*a*	62.31*a*	161.80*b*	49,285*c*	30,066.0*c*
Br	0.19	0.53	0.70	79	...
I	...	0.01	...	8.4	...
SO_4	7.69	0.03	0.05	40	...
CO_3	0.21	0.27	0.00	0	...
B_4O_7	...	...	...	150	...
Na	30.59	18.35	64.55	2,791	4,216
K	1.11	1.55	5.16		
Li	...	0.04	...	...	...
NH_4	...	0.23	...	...	...
Ca	1.20	13.86	25.19	1,425	2,792
Ba	...	...	trace	...	...
Sr	...	...	3.55	...	...
Mg	3.72	2.53	2.48	2,844	6,310
Al_2O_3	...	0.02	0.00	...	...
Fe_2O_3	...	...	...		48
Fe	...	0.25	0.16	56	
SiO_2	...	0.02	0.00	43	85
	100.00	100.00	263.64	56,721	43,517
Ratio $\frac{Cl}{Na}$	1.8	3.5	2.5	18.2±	7.5±

a. Percentage of total salts.
b. Grams per kilogram of water.
c. Parts per million (?)

A. Dittmar's summary of the principal salts in sea water, from Clarke, Data of Geochemistry, *Bulletin No.* 491, *U. S. Geological Survey*, p. 113, 1911. Placed here for comparison.

B. Brine from well 2,667 ft. deep at Conneautsville, Pa. Salinity about nine times that of sea water. Analysis by Robinson and Mabery, quoted by Clarke, *loc. cit.*, p. 174.

C. Brine from depth of 6,300 ft. in well near Imperial, Allegheny county, Pa. Analysis by George Steiger, *Journal of the Washington Academy of Sciences*, vol. iii, p. 423, 1913. Well record described by White, *Bulletin of the Geological Society of America*, vol. xxiv, No. 2, pp. 275–282, June, 1913. The salinity is eight times that of sea water.

D. Hudson well, Fredonia, Wilson county, Kan. Depth 400 ft. Analysis by Bailey and Davies, quoted in *Water Supply Paper No.* 273, *U. S Geological Survey*, p. 199 (1911).

E. Flowing salt well in Pennsylvanian strata at Lawrence, Kan., depth 1,400 ft. Analysis by Bartow and Thompson, *Kansas Geological Survey*, vol. vii, p. 151 (1902).

The following American analyses were gathered by Hofer,[1] the first four (A–D) being from oil wells near Tarentum, Pa. (analyses by Charles Lenny), and the last two (E–F) from oil and gas wells in Ohio (analyses by W. J. Root). The high percentage of calcium and magnesium chlorides is noteworthy.

	A	B	C	D	E	F
$NaCl$	3.2000	5.0203	4.7152	32.978	71.645	30.128
NaI	....	....	....	....	0.013	0.024
KCl	....	....	....	0.041	....	....
NH_4Cl	....	....	....	0.007	....	....
$CaCl_2$	0.5587	1.6462	0.9657	8.578	18.665	48.969
CaI_2	....	....	....	0.080	....	....
$CaCO_3$	....	....	....	2.764	....	....
$MgBr_2$	....	....	....	0.1154	0.271	0.592
$MgCl_2$	0.2933	0.3193	0.3132	2.166	9.826	20.201
$MgCO_3$	....	....	....	1.377	....	....
$BaCl_2$	0.0380	0.0642	0.0759	0.006	....	....
$BaCO_3$	....	....	....	0.004	....	....
$SrCO_3$	....	....	....	0.059	....	....
Al_2O_3, Fe_2O_3	....	....	....	....	0.096	0.054
$FeCO_3$	....	....	....	0.038	....	....
SiO_3	....	....	....	0.102	0.024	0.032
CO_3	....	....	....	1.953	....	....
CO_2	....	....	....	0.008	....	....

Two working hypotheses may be entertained to account for the great excess of chlorine over sodium in the water of oil fields. By the first hypothesis, we may explain the disappearance of sodium by the precipitation of sodium chloride from ancient sea water after its burial in the sediments, assuming that the Paleozoic ocean contained less sodium than the modern seas. It is improbable that the average water originally buried in the sediments of oil fields could have been a concentrated brine from which much sodium chloride had been previously precipitated. But the dryness of deep sands in oil fields, and the downward increase in salinity, suggest that beneath the zone of ground water there is a deeper dry zone from which water has been extracted, possibly through the drying influence of the ascending rock gases, which consist mainly of nitrogen, carbon dioxide, and methane. This process would precipitate sodium chloride on the surfaces of deep rock pores, leaving a residual water relatively rich in the soluble magnesium and calcium chlorides,

[1] *Das Erdöl*, vol. ii, Pl. I, p. 29 (1909). Gives 25 analyses.

which would be driven slowly upward by the rising gas. As the water passed through bodies of shale the adsorption of sodium chloride on clay particles, mentioned by Johnston,[2] might further increase the relative amount of magnesium and calcium chloride, but since potassium salts are adsorbed on clay more than sodium salts[3] the relatively high ratio of potassium to sodium in oil-field waters indicates that adsorption has played a minor rôle in their alteration.

The second and stronger working hypothesis is that the excess chlorine has been added directly as magnesium and calcium chlorides in solutions rising from below. These substances are characteristically high in oil-field waters. Furthermore, it appears that the waters of the Ohio oil fields are converting limestone into dolomite, indicating that the water which accompanied the oil in its invasion of the Trenton limestone was rich in magnesium, as it still remains. Bownocker states that the percentage of magnesium in the limestone increases as one approaches an oil pool, reaching a maximum in the pool itself. Some have suggested that this is merely a question of the relative porosity of dolomite and limestone, but the factor of porosity, although very important, does not explain the whole question. It fails especially to correlate the phenomena with the characteristically high percentage of magnesium in the waters of oil fields, and with the occurrences of secondary dolomite in the coastal fields of Louisiana, Texas, and Mexico. The lenses of dolomite or of dolomitic limestone which cap many of the salt cores of the Gulf coast are clearly secondary deposits which grew within the strata. They were precipitated from the same solutions that deposited the sodium chloride, or at least from solutions which followed the channel made by the plug or core of rock salt. The localized occurrence of dolomite, which is so intimately associated with oil near the coast of the Gulf of Mexico, and in Ohio, Indiana, and Canada, is therefore regarded as the direct or indirect product of solutions rich in magnesium chloride. The bitter brine found in the latter fields is thought to have produced the local dolomitization of the Trenton limestone.

The source of the magnesium and calcium chloride as well as of much sodium chloride may be found theoretically in the emanations from deep-seated basic rocks rich in magnesium, such as the olivine-basalt which is so intimately tied with the occurrence of oil in Mexico, and the peridotite in the dikes of western Kentucky, or the serpentine at Syracuse, N. Y., which are the only igneous rocks known near the northern oil region. Moreover, it is rock of this general character which contains diamonds in South Africa, Arkansas, and other places.

[2] Discussion of paper by J. A. L. Clerc and J. F. Brezeale, *Journal of the Washington Academy of Sciences*, vol. iii, p. 198 (1913).

[3] Clarke: Data of Geochemistry, *Bulletin No.* 491, *U. S. Geological Survey*, p. 200 (1911).

Stelzner, Bonney and others have proved that the diamonds of the Kimberley district crystallized as an integral part of the magma and that the carbon is of deep-seated origin. In Cuba there is a remarkable series of occurrences of light oil in serpentine. In similar rock Diller has found metallic iron which probably contains carbides. Magnesium-rich magmas therefore are the most probable source of oil (if it be volcanic) and of the accompanying chloride solutions.

The acceptance of the idea that modified volcanic emanations have entered the strata of oil fields simplifies many problems besides that of the relative excess of chlorine. For instance, it furnishes an adequate cause for the localization of the great salt-cores of the Texas, Louisiana, and Chiapas. Harris[4] finds that the salt domes of Texas and Louisiana have a linear arrangement suggestive of long intersecting fissures. He finds that the amount of uplift of the strata is entirely inadequate to account for the amount of space occupied by the salt plugs, some of which have been penetrated by the drill nearly 3,000 ft., without reaching bottom. He concludes, therefore, that the salt cores are not laccolithic or plug-like intrusions into the sediments, squeezed up from a great hypothetical salt bed in some lower formation, but rather that they have grown by crystallization at the places where they now occur and have not undergone much deformation. In other words, they are great cylindrical concretions of salt 1,000 ft. or more across and over 3,000 ft. high. He believes that the salt and the associated hydrocarbons were gathered by meteoric waters which percolated through the sedimentary strata and rose along the intersections of fissures, where the salt was precipitated because of the decrease in temperature and pressure. The decrease in pressure would cause but a negligible precipitation, practically nothing. Temperature is somewhat more effective, but Lindgren[5] says: "As the solubility of salt increases only slightly with increase of temperature (35.69 per cent. at 10° C.; 39.12 per cent. at 100°; 44.90 per cent. at 180°), only the increment could have been precipitated as the temperature of the ascending current was lowered, and hence the quantity of primary salt required by this hypothesis is incredibly large." Let us assume that the solutions cooled as fast as the normal underground heat gradient, or about 21° C. in ascending 2,000 ft. This would precipitate about 2 per cent. of the total salt in a

[4] *Bulletin No.* 429, *U. S. Geological Survey* (1910). The alignment of the salt domes was first observed by Captain A. F. Lucas: Rock-Salt in Louisiana, *Trans.*, xxix, 463, Fig. 1 (1899). Captain Lucas was also the first to observe the geological relations of the salt cores with reference to the occurrence of oil, which he proved by drilling the famous "Lucas gusher" at Spindletop. *Cf.* Robert T. Hill: *Journal of the Franklin Institute*, vol. cliv, pp. 143, 225, 263 (Aug.–Oct., 1902). A. F. Lucas: *Science*, vol. xxxv, pp. 961–4 (June 21, 1912). *Economic Geology*, vol. vi, No. 4, p. 380 (June, 1911).

[5] *Mineral Deposits*, p. 288 (1913).

solution saturated at 100°. In other words, the salt cores would represent only about 2 per cent. of the total amount of sodium chloride which had risen in the fissures, the rest having been carried beyond the top of the cores and lost. The salt cores in this country and Mexico number several hundred and their total volume is many cubic miles. The theory of Harris, if not modified, requires a supply of roughly 50 times as many cubic miles of salt.

Yet the "concretionary" theory of Harris has much in its favor, since it meets the mechanical requirements of the problem better than any other. The chemical difficulty can be met if the salt domes have been the *loci* of the escape of solutions carrying a common ion, either of sodium or of chlorine. Analyses of some volcanic waters show an abundance of sodium chloride, and others of sodium sulphate or carbonate, but these do not meet the requirements of the present problem. From the character of the water and from the presence of secondary lenses of dolomite one may infer that the precipitation was produced by the intermingling of concentrated salt solutions with brines rich in magnesium and calcium chloride. The former were probably derived mainly from the sedimentary strata as suggested by Harris, but the latter probably rose from underlying plugs of olivine basalt which failed to reach the surface.

Plugs and dikes of this type of rock are common in the coastal plain of Mexico, where they have about the same relation to the occurrence of oil as do the salt cores in Texas to the north or in Chiapas to the south of them. The chlorine probably escaped from the magma as free chlorine, as hydrochloric acid, and as chlorides of ammonium, calcium, magnesium, and sodium. If the igneous plugs are not too deeply buried beneath the plains it is probable that large quantities of hydrochloric acid passed up through the overlying fractures made by the intrusion of the plug. This is the most effective precipitant of common salt, and in the case of the fields about the Gulf of Mexico, the evidence of volcanic action is so strong as to suggest that hydrochloric acid may have played an important rôle in the precipitation of the salt above the volcanic plugs. Also magnesium and calcium chlorides would be quite effective to precipitate rock salt, and if the ascending igneous emanations passed through many strata before reaching the horizon of the salt cores it is certain that the hydrochloric acid would be all converted into chlorides, largely into the chlorides of calcium and magnesium. For our present argument it is immaterial whether the chlorine ions were attached mainly to hydrogen, to calcium, or to magnesium. According to Nernst's law, any of these probable chlorides would precipitate sodium chloride from a concentrated solution. In this way masses of salt derived from the sediments would be formed

where the sedimentary solutions mixed with the rising solutions of volcanic chlorides, *i.e.*, directly above the deeply buried plugs.

Thus the volcanic hypothesis offers a simple explanation of the salt and dolomite problem of oil fields, and the relative excess of chlorine in the associated water may be regarded as a possible indication of the entrance of volcanic emanations, which in most cases have been greatly modified by their long ascent through the rocks.

Discussion

A. F. Lucas, Washington, D. C.—I have long held the opinion that igneous rock may underlie the salt domes of Louisiana, Texas, and elsewhere, resembling laccoliths, batholiths, or sills, and an unsuccessful attempt to prove this was made at my instance by the drilling of the Knapp well at Belle Isle, La., which passed through over 3,000 ft. of rock salt (the first time to my knowledge that a salt dome has been pierced), then entered into sedimentary, striking first an oil sand giving about one barrel of red paraffine oil, then limestone, calcite, or dolomite (not positively ascertained), until a total depth was reached of about 3,300 ft., when the well was lost by the collapse of the casing.

At the extreme bottom the drill was working on very hard formation, which it could not penetrate, although repeated attempts were made, nor was it possible to secure samples of this rock, which, from its extreme hardness, I surmised to be possibly some igneous rock, or perhaps iron pyrite.

Eugene Coste, Toronto, Canada.—I agree entirely with Mr. Washburne's view that the strong salinity of these waters in the oil fields is due to solfataric volcanic emanations; the composition of these waters, not only the large excess of chlorine in them but the excess of magnesium and calcium, differentiates them entirely from sea waters and they can only be compared with magmatic waters. In the Texas and Louisiana oil fields we certainly have the clearest examples of solfataric action which we have in the oil fields of the United States—I mean in the salt domes of Louisiana and Texas, where secondary products, not only of salt in large bodies, but enormous bodies of dolomite, gypsum, and sulphur, have been deposited in vertical chimneys by solfataric hot waters accompanied with hydrocarbons and sulphuretted hydrogen; the salts being impregnated with natural gas, sulphuretted hydrogen, and oil, and the salt waters and the oils being quite hot yet in some cases.

A. C. Lane, Tufts College, Mass.—Mr. Washburne's paper brings forward some interesting points; and his main thesis, that these are derived from within (juvenile), is one well worthy of careful consideration. Does he not, however, assume that the early sea water had a character

too much like that at present? Judging from the average water now received by the ocean, either according to Murray or Clarke, there *must* have been a gradual change in its composition, as Hunt, Goessman and I have pointed out, not only in increasing salinity but in the relative proportions of the different salts.

It would be interesting for him to extend his collections of analyses to a wider range of geological horizons. Those cited are Paleozoic. In a paper on the chemical evolution of the ocean, yet unpublished, I have shown reason to believe that while underground circulation tends to run up the ratio of Na : Cl, the character of truly stagnant water varies with its geological age.

The trouble with following his suggestions and connecting the calcium chloride waters of the Lake Superior mines with the highly calcic magmas of the greenstones associated is that the calcium chloride waters occur just the same in the felsitic conglomerates interbedded and also in far-removed sandstones, *e.g.*, near Whitefish lake and Ontonagon, in the Michigan iron mines, and in the Storm King granite. If we are to look to an earth sweat for these universal waters, then I think it would be better to assume the chloride merely to be slowly diffused from the interior, picking up its bases *en route*. But a serious difficulty there is that we have, for instance, under the oil-field waters referred to by Washburne, the St. Peter sandstone, with a water which is much fresher, apparently cutting off any prospect of a juvenile source, which otherwise I should be delighted to accept.

The objection to Washburne's theory is the fact, if it be a fact, that different geological horizons have different chemical characters, and that if not too much disturbed by circulation they can be recognized thereby.

The Maritime Features of the "Crude Petroleum" Problem

BY REAR ADMIRAL JOHN R. EDWARDS, U. S. NAVY, WASHINGTON, D. C.

(New York Meeting, February, 1914

Introductory.—There are many interesting and important events connected with the petroleum problem. The remarkable men who conceived the thought of transporting petroleum by pipe line, conserving the by-products of the commodity, and conducting extended investigation and research whereby the flash point of the oil was raised, its cost reduced and its supply assured, are deserving of the gratitude of this nation.

It was primarily the success attained by Captain Lucas, after his comprehensive search for oil in Texas and Louisiana, that was the impelling cause which prompted the Navy Department to conduct the extensive series of liquid fuel-oil tests that were made from 1901 to 1903. The sensational discovery of oil at Spindle top made a deep impression upon Rear Admiral George W. Melville, then Engineer-in-Chief of the Navy, and the discovery of the vast oil field in Texas convinced him that, within a generation, if not within a decade, crude petroleum was going to play a very important part in warfare, and that the commodity might possibly develop into a necessary munition of war.

The United States' Commanding Position as a Petroleum Producer.—In the study of the various problems relating to the world's production of crude petroleum, the position of the United States is one of commanding importance, whether viewed from the industrial or the military aspect.

The present yield of this country is practically double that of the rest of the world, and, in view of the productive and prospective fields possessed by various countries, together with the comprehensive and exhaustive search that has been made throughout the world for petroleum, it is extremely probable that this lead will be maintained for the next decade.

As regards the character of the crude-oil yield of different countries, America possesses the greater part of the supply that contains a paraffine base, and therefore a considerable portion at least of the American product produces the best illuminant. Of all the crude-oil distillates, kerosene is in many respects the most important, and the Appalachian product for this purpose is favored, particularly in the Far East, above that of any other petroleum yield of the world.

We are undoubtedly in advance of any other nation in the extent and character of our prospecting and drilling facilities, and this is attested by the fact that American experts are found in nearly all the other oil districts of the world, directing the activities of production.

In methods of refining our position is on a parity with others, if not a commanding one. We have been able to obtain from the crude product various distillates of as high character, and at as low a cost, as can be produced by the foreign refineries. New and important uses are being found for the by-products of crude oil, and our discoveries in this direction may undoubtedly be regarded as important as, if not superior to, those of our rivals.

In methods of land transportation our lead is undisputed. This should not be surprising, considering the extended and diversified experience that we have had in the construction of pipe lines, pumping stations, and containing tanks, as compared with the relatively limited experience of the rest of the world.

The United States' Weakness as Regards Ocean Transportation.—There is one important feature of the fuel-oil problem, however, wherein we are lamentably weak, and that is the maritime distribution of the product from the terminals of the pipe lines to various important seaports of our own country, as well as to ports abroad.

The modern sea-going tankers that we possess are few in number as compared with those that fly the ensign of Great Britain. Our failure to convey or distribute crude oil in as efficient a manner as we produce, refine, and transport the product, constitutes a serious industrial reproach to our commercial abilities. When viewed from a military standpoint, our lamentable dearth of ocean tankers and sea-going barges constitutes a great military weakness.

Our Lack of Sea-Going Oil Craft Entails Heavy Direct and Indirect Loss to American Industrial Activities.—It appears incongruous that a British corporation should find it a profitable venture to spend millions of dollars in prospecting for oil in Mexico, Ecuador, Colombia, and other Central and South American republics, when our own capitalists ought logically to undertake the practically exclusive development of those fields.

The British corporations engaged in petroleum development cannot possibly have the intimate professional knowledge and extended practical experience that is possessed by our own experts. Our banking interests are likewise undoubtedly as ready to advance capital in the exploitation of legitimate fuel-oil enterprises as the financial interests of England. It appears evident that it is only because the American maritime feature of the fuel-oil problem is so unsatisfactory that it has been possible for the Pearson Corporation in Mexico to compete against the American interests in that country.

As illustrative of the deplorable condition of affairs as regards the maritime feature of the crude-petroleum problem, it is pertinent to call attention to the fact that, when the Liquid Fuel Board of the Navy was conducting its extended series of fuel-oil tests from 1901 to 1903, an investigation that extended over a period of 30 months, and an investigation wherein there were expended at least a quarter of a million dollars, there were several periods when the President of the Board was informed that, for two or three days at least, there was not one single American tanker carrying fuel oil between the Texas terminal ports and the leading seaports on the north Atlantic coast. Careful investigation was made to determine if such a condition of affairs actually existed, and, from the best information obtainable, there was one period, if not two, when it happened that every American sea-going tanker was either temporarily disabled, detained in port, or had met with some delay so that no oil vessel was steaming between the Gulf and north Atlantic ports.

It is possible that, at these two particular periods, one or two such tankers may have been proceeding with empty compartments to the Gulf for a cargo of oil. It may be stated as a fact, however, that in 1901 or 1902 a situation arose whereby, for at least a few days, not one gallon of crude oil was being transported by water from Texas to northern ports. There were, of course, during this special period, considerable quantities of oil being transported in barges from the terminal pipe lines and refineries at Baltimore, Point Breeze, Marcus Hook, and Bayonne to other points on the Atlantic.

As bearing upon the question of the world's dearth of oil tankers, it may be well to call attention to the fact that, about 18 months ago, the Paymaster-General of the Navy made an effort to find out the number and character of the tankers that could be chartered at short notice by the government. It was found at that time that it would not be possible to secure at short notice one single American tanker on the Atlantic coast; every tanker flying the American flag being required to convey the oil that was used for industrial and other purposes by regular consumers.

A still greater surprise was experienced when it was found that but one British tanker could be procured at that period, and that this vessel could only be chartered by the Navy Department by the payment of a rental of $575 per day, which rental did not include fuel and port charges. This rental had to be paid from the date the British tanker was chartered in London, and was to continue until the return of the vessel to the same port.

It seems surprising, if not astounding, in view of the fact that we not only surpass the world as regards the yield of the crude-oil product, but that likewise we possess advanced methods of boring, improved

processes of distilling, and incomparable methods of land transportation, that the maritime feature of the oil industry should have been neglected by this nation.

Profits of the Oil Industry have been in the Refining and Transportation of the Product.—In the study of the extensive and far-reaching report of the Commissioner of Corporations, as contained in the government's brief against the Standard Oil Co., it is observed that the principal profits of that corporation have been in the refining and the transportation of the oil, and not in prospecting and drilling for the product. The distribution agencies, however, have been inadequate, except so far as they concerned districts fairly contiguous to pipe lines, refineries, and deep-water terminal points. At such particular points, which must necessarily be limited in number as compared with the rest of the country, the distributing facilities have been efficient, considering the expense, difficulty, and hindrances encountered in distributing all inflammable hydrocarbon products. There is no doubt, however, that every interest concerned either in prospecting, boring, refining, or distributing crude oil has been very materially injured by our failure to control the distribution by sea.

The Importance of Petroleum as a Factor in Extending Our Foreign Market.—Fuel oil has played a very important part in extending our trade with China. The writer, in the course of his duties as a naval officer, spent about 6 years in Asiatic waters, and interviewed various American and British Consuls, as well as the leading merchants of the China coast, in reference to the far-reaching influence of the petroleum industry. The study of our trade development with China must cause one to be impressed with the fact that the three distinguishing agencies which have done most to cause the Land of Sinim to abandon many of its traditions and much of its medievalism have been the missionaries, modern surgery, and the work of the Standard Oil Co. In distributing throughout that country an illuminant that has been a direct boon to the people, the Standard Oil Co. has exerted an indirect influence that has been of far-reaching consequence in extending our trade relations with that Empire.

Light is a great civilizer, and the remarkably convenient, economical, and safe manner in which the Standard Oil product was distributed, even to the wilds of Hunan, was the forerunner of the entry in large quantities of other American products.

In the distribution of refined petroleum in cases rather than in bulk, our country attained for some time considerable success in the employment of sailing vessels. We lost, however, a great opportunity in not effecting legislation that would have retained to us this trade by regulating the export of the product, and that would have given to this nation a paramount control of the distribution of petroleum.

The writer was on the China coast about the period when the Russian oil interests, supported by the Rothschilds and other great banking interests of Europe, attempted to wrest the control of the petroleum industry from America. Modern steel oil tankers were built for the Rothschilds for this purpose, and large containing tanks were erected on shore at various points on the China coast. It was found, however, that the American product was so superior in quality as an illuminant, and it was so well contained and boxed, that it was practically impossible to supersede its use by the substitution of the Russian product.

It was not by a haphazard guess or by accident that the existing 5-gal. rectangular petroleum case was constructed. The form of the containing case, the material from which it is manufactured, the character of the soldering and the method of boxing and shipping constituted a development that represented heavy expenditure, extended experimentation, and practical knowledge upon the part of the Standard Oil experts.

In distributing this product, therefore, even unto the uttermost portions of the Chinese Empire, the Standard Oil Co. rendered a service of incalculable benefit, both to China and to America. If it had not been for the energy, efficiency, and tact displayed in developing our petroleum export trade, many looms in New England and many furnaces in the Appalachians that are now finding it a profitable venture to export their output to the Celestial Empire would be idle to-day.

It is believed that the American export trade of the future to Central and South America, Australia, and particularly to China, is greatly dependent upon the distribution or maritime feature of the fuel-oil problem. This phase of the oil problem is therefore a matter that is specially worthy of the consideration of the American Institute of Mining Engineers, for it is the mining engineer who is most intimately interested in the primary feature of the oil industry—and that is the prospecting phase.

There is something lamentable in the thought that, despite the fact that this country has a commanding lead in all but one of the various phases of the petroleum problem, America should fall down at the last stage, and that we should see our British cousins, through their superiority as regards the maritime feature, wresting from us a maritime activity of great value—an activity that logically should be possessed by America.

The Military Importance of the Maritime Phase.—It is not opportune at this time to speak of the military features of the distribution problem, since there are phases of the matter that intimately concern national defense. The fact is well known, however, to British naval experts, and mention has been made of the subject in the English press, that our navy is lamentably lacking in the oil tankers that will be required to supply American battleships and other naval vessels that have been designed

to burn oil exclusively. The various publications of the Congress that are distributed both at home and abroad, tell of the number and character of American naval vessels that have been designed for an exclusively oil-fuel installation, and therefore our weakness as regards the number and character of the merchant and naval oil tankers that we possess must be well known to foreign military experts. The various publications issued by the government even tell, in detail, of the tonnage, cargo capacity, and other important structural features of these ships.

Our Inadequte Oil Reserve at all Our Industrial Centers in Considerable Part due to Our Maritime Weakness.—The maritime feature is an important one, from whatever standpoint the question is considered. There are hundreds of industries in this country which would substitute petroleum for coal if an assured supply of the former combustible could be maintained. There are hundreds of industries that have experimented with petroleum with the intention of using it exclusively as a fuel, that have been compelled to return to coal, due to the impossibility of obtaining an assured supply of oil.

The cost and risk of transporting oil by cars constitute an insuperable bar to the distribution of the product in sufficient quantities to insure an adequate supply for large industries. Crude oil will, however, always be used for purposes wherein a substitute cannot be found, independent of the question of cost. It is, in fact, our dearth of water-transportation facilities that prevents the distribution of the product, and therefore limits the use of petroleum. There is no doubt that there are many important industries which, with the use of oil, would produce special articles that would find a ready and profitable sale in foreign countries, if they could be guaranteed that they would be able to get all the oil they required. It is well known that petroleum is an incomparable fuel for many industrial purposes, but no manufacturer dares to use the product except to a limited degree, unless his plant is so located that he can be assured of an adequate supply at other than a prohibitive cost.

Should not an Export Duty be Placed upon Petroleum Products when Carried in Foreign Bottoms?—When it is considered that the United States furnishes about two-thirds of the world's yield of crude oil, and that it is somewhat probable that, at least in this country, the maximum of annual production has nearly been reached, unless there are vast undiscovered pools of oil at lower depths than we are now able to drill, it ought to be possible for this nation to so regulate the export of the product as to conserve the industry in a manner that will best help ourselves, if not mankind. There are undoubtedly in the United States a sufficient number of steamship companies, railroads, and individual firms that would use all the oil produced in this country, if such plants could be assured of an adequate and reliable supply, and therefore the foreign export of oil may not be necessary in the disposal of the apparently large quantities produced.

In many industries the cost of the product is not a serious matter as compared with the particularly beneficial and industrial results that could be expected to accrue. It is all-important, however, in every enterprise, that, once an industry adopts a special form of fuel, such plants should be assured that an adequate supply of that fuel could be promptly obtained

Many of the distillates of crude oil should even be regarded as munitions of war, and legislation should be enacted that would make it possible for us to prevent the export of oil at such times as we deemed advisable. Except for a brief period, it is extremely probable that, if we placed an export duty on petroleum, no permanent financial injury would accrue to any one interested in the drilling, refining, transportation, and distribution of the product. The writer has been told repeatedly, during the past 10 years, by various manufacturers and individuals, that it was solely the lack of assurance than an adequate supply of crude oil would be available that prevented them from using the product.

Probably no better way of helping to give the American merchant marine a reasonable share of the foreign oil-carrying trade could be devised than by placing an export duty on every barrel of oil exported from the United States in ships carrying a foreign flag. We are one nation that is unreservedly adopting the policy of fitting our battleships with an exclusively oil-fuel installation, and this installation is of such a character that, except at enormous expense, the structural change to coal-burning arrangements cannot be brought about. One of the most effective ways, therefore, of providing a supply at various points for naval purposes is to conserve the petroleum industry, by taxing the export of the product and by exercising the prerogative that logically belongs to us in controlling, to a limited degree, the sale of the commodity.

International comity and the law of nations sanction the policy of a nation placing an export duty on a commodity that it substantially controls. We are therefore justified in taking some radical means to control the maritime phase of the matter.

In the consideration of the problem of imposing an export duty upon petroleum, there are several phases of the question that merit thoughtful consideration and investigation. If serious thought is ever to be entertained of the proposition of imposing an export duty upon crude oil, the question may well be asked: "How will it affect our trade relations with China? Is the American illuminant of such superior quality that the Chinese would pay the additional cost that would be the result of such action? Have the foreign competitors of the Standard Oil Co. effected such improvements as regards refining the product that they can now furnish as good an illuminant as that which can be obtained from the paraffine-base product of the Appalachian region? Are our foreign competitors already making serious inroads into the sale of the American product in various countries? Would the loss of the petroleum trade of

the foreign countries, and particularly the petroleum trade of China, be followed by a marked reduction of other American imports into those countries?" The question of an export duty is therefore one which admits of a wide divergence of opinion.

Conservation of Our Oil Resources.—The conservation of our oil industry can only be brought about by some national organization like the American Institute of Mining Engineers taking advanced ground upon the subject, and urging that early and thoughtful action be taken in the matter. Various individual officials of the government, as well as individual experts, have urged such a course, but such individuals do not, in many respects, possess the machinery for being the proper central agency in bringing about such important action. The influence of the American Institute of Mining Engineers extends throughout the country, and, if it should recommend some thoughtful line of policy in the matter, there is no doubt that various commercial exchanges and maritime associations of the country would supplement the work of this Institute.

There is no doubt that the high purpose and urgent necessity of conserving the petroleum industry can be brought about in various ways, but the more study one gives to the matter the more impressed he becomes with the fact that, in the control of the maritime phase and in placing an export duty on oil shipped in foreign bottoms, it ought to be possible to do much, not only in conserving the industry, but in helping to bring about the restoration of the American Merchant Marine.

Efficiency of Our Oil Tank-Car Facilities as an Agency in the Distribution of Petroleum Products.—By reason of the wide extent of our country, the diversified character of its industries, and the limited number of existing oil pipe lines, the greater portion of the distribution of the crude-oil product will have to be done by cars. The existing design and arrangement of these cars represent extended and thoughtful development. The facilities for the safe and economical storage and handling of petroleum products are undoubtedly in many respects of the most efficient nature, and there is no doubt that all persons connected with the crude-oil industry are exceedingly receptive of counsel and advice that will improve the oil tank-car arrangements.

When there are considered the insurance and regulations, the danger attendant upon the transportation of oil by cars, together with the limited facilities for the storage of such combustibles in our various industrial cities, it becomes a question of paramount importance that wherever possible the car facilities should be supplemented in some manner, and that a greater distribution of the oil product be brought about by barge or through some other maritime agency. However great may have been the shortcomings of those controlling the petroleum industry, there is no doubt that, so far as tank-car equipment and storage facilities are concerned, an exceedingly earnest effort has been made by

the oil corporations to bring an adequate amount to the various industrial cities, and to store it in as convenient a location as possible. The oil-distributing companies, however, have been confronted with the problem that, at every important industrial center, there exists not only a dearth of oil tank cars, but a lack of freight-handling facilities. It has not therefore been possible, by reason of existing railroad terminal facilities, to give preference to the distribution and handling of crude oil when the railroad companies are confronted with the more serious and more important problem of handling the daily food supply of these great municipalities; and this, in general, is one of the reasons why manufacturers cannot get the oil they need.

Our Lack of Merchant Marine a Serious Bar to the Development of the Crude-Oil Industry.—One can well understand that it has been primarily due to the lack of suitable oil barges and tankers that makes the sea-going distribution, or maritime, phase of the problem a matter that concerns our industrial life. Under existing conditions the transportation of oil in American vessels to foreign ports is substantially a venture impossible of profit. On the Pacific coast it may now be possible; but, with the development of the Mexican fields and the opening of the Panama Canal, we may lose even that trade. The cost of operation of American-manned ships has been so great, as compared with the operation of foreign ships, that it is certain we cannot hold any foreign trade, and therefore it has fallen into the hands of our foreign rivals. The indirect financial loss to this nation in the loss of the petroleum export trade has undoubtedly been of vast extent. American crude petroleum is one of the products that is favorably received, if not eagerly sought, in foreign countries, and therefore the control of this special trade is of far-reaching importance to our manufacturing interests at large. Following the importation of petroleum products into foreign countries, there has almost invariably been a progressive increase of imports of other American articles to such countries. It therefore appears that, if there is one industry that needed the support of the government, or even that should have been heavily subsidized, it is that relating to the carrying of crude oil in American-registered ships.

Nation's Reserve Stock of Crude Petroleum.—It is significant to note that the petroleum stocks on hand in the United States at the close of 1913 approached about 130,000,000 barrels, a quantity that would not meet the nation's existing consumption for a period exceeding eight months. On Jan. 1, 1913, the reserve stock was actually less than that on hand Jan. 1, 1912. During the past year, however, there has been a slight increase in the reserve stock, although drilling for the product was stimulated in every State in the Union as a result of the increased price obtained for substantially every distillate and by-product of crude oil. It is of exceeding commercial, if not military, interest, likewise, to

remember that the yield for 1913 from every oil-producing State except California and Oklahoma was less than the yield of some previous year, despite the fact that progressively increased prices were obtained for the oil in every district of the country, and that oil fields which had been abandoned in previous years are now able, under existing conditions, to yield a profitable return upon the capital invested.

A very distinguished authority upon the California product has recently declared that, despite the continuous and careful research that has been made for oil in that commonwealth, the possible productive area of that State appears to be about 2,000 acres beyond that established in 1909, when Secretary Garfield, then the executive head of the Department of the Interior, ordered a survey to be made. He furthermore said that in all probability, nearly every crude-oil basin within that State had been located, and that there would be a constant drain and reduction in the reserve stocks that could be maintained there. In fact, another expert has asserted that, due to water intrusion and certain wasteful methods of production practiced in California, this country should be prepared to note a startling slump in the oil production of California. The wasteful manner in which drilling is being carried on in that State, taken in connection with the fact that the most important wells can henceforth be expected to show a progressively decreased supply of the product, affords some ground for the belief that the curve of production in that State may suddenly drop like the hump on the back of a camel.

As regards the thousands of miles of productive fields that are supposed to exist in Mexico, the United States Geological Survey, in its Advance Bulletin for 1914, states that, despite the phenomenal energy of crude-oil exploration work in Mexico, the fact remains that so far as the present supply is concerned the Mexican yield has been practically limited to a few large wells, and not to a very large number of smaller wells. It is questionable, also, whether many new wells are likely to be drilled under the peculiar conditions that exist in Mexico at present, and that may possibly exist for years, as regards shipments. It is extremely probable that the supply will not be sufficient to meet the demands of the numerous large-sized tankers that have been contracted for to carry the product from Mexico to England. It must further be considered that, with greater confidence developed as regards the Mexican supply, the price per barrel may increase rather than be reduced, because an assured supply from that country will not only stimulate refining, but tend to increase the oil consumption throughout the world. At present the Mexican yield is but 5 per cent. of the total yield of the world, and there is substantial evidence that most of the promises as regards Mexican development are not likely to turn into performances. It is even going to be for some years quite a serious matter to safeguard the Mexican wells from destruction at the hands of brigands and insurrectos.

The Military, if not the Industrial, Necessity of Installing Additional Pipe Lines to Certain Points on the Atlantic Coast.—By reason of the fact that the vicinities of Cape Hatteras and Cape Cod constitute certain storm centers, the insurance companies of the United States charge additional rates on ships that pass near these storm points. These additional rates of insurance likewise apply to the cargoes carried by the vessels. While the rates for approved sailing-ship transportation are less than those demanded for approved steamship transportation, the fact remains that all classes of vessels, whether steam or sail, are made to pay an extra insurance charge of about 10 per cent. when plying within range of the lighthouses of Hatteras and Nantucket.

There are undoubtedly urgent military reasons, if there is not an industrial need, that the leading transporting oil companies should extend their pipe lines to some point on the Atlantic coast south of Hatteras, and to another point either on Narragansett or Massachusetts bay. An oil pipe line leading to New England ought to prove a paying venture at least in the course of a few years, by reason of the increased quantity that would be consumed there, and the higher prices that would be willingly paid by the manufacturers if they could be assured of an adequate and reliable supply.

In the manufacture of illuminating gas, crude oil is an important and essential constituent, and it ought to be possible, without in any manner impairing the financial interests of those engaged in oil transportation, to make the New England project a desirable investment. The number and character of the industrial cities between Bayonne and Boston, and the possible extent to which crude oil could be used in the industries of those cities, ought to warrant the building of a New England oil pipe line.

However numerous and however large may be the containing tanks that may be installed, but which must be supplied either by tank cars or by sea-going barge or ship, there will be periods, as long as we depend on tank cars and due to the railroad terminal conditions at all our leading industrial centers, when the reserve stock will be of such a limited nature as to prevent certain users from obtaining an adequate supply; and it is for this reason that there appears to be an industrial necessity for a New England oil pipe line.

The construction of a pipe line from the West Virginia fields to some port south of Hatteras—a port which possesses the deep-water facilities of Charleston, is a national necessity, and if necessary its construction should be subsidized by the government. The far-reaching influence of providing an ample supply of oil to naval vessels alone cannot be overestimated, and a pipe line to some point on the Atlantic coast south of Hatteras may eventually develop into a military necessity. Our seagoing battleships that are fitted with exclusively oil-fuel installations, together with numerous destroyers that burn oil exclusively, require

terminal pipe-line facilities at some point south of Cape Hatteras, and the construction of a pipe line from the West Virginia fields to Charleston ought to be given early consideration. Fortunately for the interests of the Navy, there are several oil pipe lines leading to Gulf ports.

The General Problem of the Conservation of Petroleum Should be Considered by a National Commission of Experts, Representative of all Interests Concerned in the Question.—Neither the direct value nor the indirect worth of the ocean oil-carrying trade to a nation may be within our power to estimate. The far-reaching importance, however, of the maritime feature of the petroleum problem is best evidenced and manifested by the fact that, although the petroleum yield of the British possessions does not comprise even 1 per cent. of the world's production, there was appointed on July 30, 1912, by the British Ministry, a Royal Commission on Oil Fuel for the Navy. This Commission was headed by the ablest naval officer, in some respects, that has been borne on the Navy List of England since the days of Nelson.

In order to demonstrate the importance which Great Britain attached to the work of the Commission, the personnel of that body included the Director of Naval Construction, the Engineer-in-Chief of the Navy, representatives of the shipbuilding firms and shipping interests, together with representatives of every important interest concerned in the extension and development of the petroleum industry.

While this Commission has made several confidential *ad interim* or preliminary reports, it is extremely important to note that this distinguished array of experts has not yet found it possible to submit its final report to the British Ministry. These experts evidently believe that the more study that is given the matter, the more important appear the possibilities.

If there were impelling reasons upon the part of the British Ministry to appoint such a Commission, although England's distinctive industrial interest in the matter is primarily based upon the distribution feature of the oil product, it would appear much more important that this country should give equal consideration to the problem. In fact, however, it is the military possibilities of the problem that concern Great Britain; and should we not be more concerned as to this phase of the problem?

The Liquid Fuel Board of the Navy, a Board which carried on the most exhaustive series of tests that have ever been conducted in determining the relative value of coal and oil as a fuel, made the following recommendation in submitting its report in 1903. It is pertinent to state that these tests continued over a period of 30 months, and that the direct and indirect expenditure involved in the work exceeded a quarter of a million dollars.

"In view of the fact that 48 per cent. of the world's output of crude petroleum is produced in the United States (it is now 63 per cent.), and that practically our entire

yield is secured from fields which are in pipe-line communication with important maritime and strategic ports, the Board considers that a joint commission, representing commercial, manufacturing, and maritime and naval interests, should be authorized by the Congress, whose provisions it would be to formulate such rules and regulations as would provide for the economical, efficient, enduring, and safe fuel installation."

Far-reaching as may have been the above recommendation, there have been such important developments in the petroleum problem during the past 10 years that it now appears more imperative than ever before that such a Commission should be appointed. Its duties should be of a much more extensive nature than recommended by the Liquid Fuel Board of the Navy. Its scope of inquiry should include every feature of development from prospecting for the product to the distribution of the commodity. Particularly should its work include the important problem of conserving this great industry to the benefit of our commerce and the defense of this nation.

This meeting of the American Institute of Mining Engineers affords an opportune time for giving some serious consideration to the question of conserving the petroleum industry, and to the appointment of a national Commission that would outline the nature of the work that should be entrusted to such a body.

The Use of Petroleum in Dust Prevention and Road Preservation

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PREVIOUS to the introduction of the motor vehicle the broken stone or macadam road met the conditions of rural horse-drawn traffic better than any other type of road, but under fast motor traffic it has been proved to be quite unsatisfactory, and necessitates high maintenance charges. Such a road depends for its success upon the fact that the rock dust fills the voids between the stones and acts as a cement or binder. Under ideal conditions it should be constructed of rock so suited to the volume and character of horse traffic that only enough fine dust is worn from the stones of which the road is composed to take the place of that carried off by wind and rain; and when these conditions are met, the fine dust resulting from the wear of traffic forms with the stone a smooth, impervious shell, shedding the surface water and protecting the foundation. With increase in the number and speed of motor vehicles, however, it was soon found that the cost of maintenance also increased, until at the present day highway engineers consider the old method of constructing and maintaining broken-stone roads increasingly inadequate, and are introducing every known type of binding material other than rock dust to cement the stone together. Among the most prominent types of products in use are those produced from our various petroleums.

That the value of modern methods of road preservation was appreciated in this country much earlier than we have been accustomed to believe is demonstrated by the recent revival of an old patent which was granted to one John Martineau, of Elbridge, N. Y., in 1834. Petroleum had, of course, not been discovered at that time, but he claims as his invention and improvement "The application of tar, turpentine, or any of that class of tenacious, cohesive substances, reduced before use to a fluid state, and that state used as a cement, to apply to, and combine with sand, gravel, pebbles, and pulverized stone, such as is used for a McAdam road, or cobble stone, the interstices of coarser material being in all cases filled, as well as may be, with sand and gravel and cemented with tar or turpentine, to form the wearing face or surface of streets,

* Non-member.

roads, etc., in the manner described in this specification." The specifications are, moreover, of rare interest in that they forestall our modern ideas of dense mixture by specifying "Whatever kind or variety of materials are selected in any particular case, the whole should be rendered as compact and uniform as possible. If coarse materials enter into the composition in any case, finer materials should be combined therewith to fill the vacancies, render the mass solid and compact, and the upper surface smooth and even." A general type of distributor is also described which embodies the principal features, excepting high pressure, of machines in use to-day.

The beneficial effect of oil on roads was observed in the early days of the development of the Pennsylvania oil fields. Through tracking and dropping, appreciable quantities of oil naturally came upon the surface of the various roads communicating between the wells, and although no systematic use of the observation was made, it was noted that a denser, more compact surface was formed, with the elimination of dust.

However, these early observations never came into prominence and it may be said that experiments in California were the forerunners of our recent developments in the application of oil to roads. In 1894 crude Summerland oil was applied to the earth roads of Santa Barbara county, and the results proved so successful that the practice rapidly spread throughout the State. The character of the native crude oil together with peculiar soil and climatic conditions favored the success of this type of improvement in the locality where it originated, and it was not long before the fame of the California oiled road became widely known. This naturally led to similar experiments in the East, but these met with mixed success and failure owing to the widely varying character of the available oils and different local conditions.

The California oils are, as a whole, distinctly asphaltic in their general character, consisting essentially of the unstable polycyclic polymethylene hydrocarbons which characterize the native asphalts. They possess decided adhesive properties and the property of rapidly hardening or "setting up" upon exposure to atmospheric influences. The oils from the other fields of the United States vary from those of the Appalachian and Ohio-Indiana fields, which are composed largely of saturated paraffin hydrocarbons, to those of the Gulf field, which contain a larger percentage of unsaturated hydrocarbons and are frequently characterized as semi-asphaltic. The former are of a naturally greasy consistency and cannot be made to develop any adhesive properties by refining processes. They possess a certain value as dust-layers, where the purpose is simply to hold down by capillarity the dust which has already been created upon the road surface. Their effect is temporary, and the necessary frequency of application is dependent on local conditions. The same general statement is true of most of the crude oils from other fields, excepting

California, although the so-called semi-asphaltic oils, on account of the nature of their hydrocarbons, can be made to yield satisfactory products for surface treatment and road construction.

During the past two or three years two hitherto unknown types of petroleum have come into prominence—the Trinidad and the Mexican oils. The more fluid grades of both are similar in that they consist of a relatively large amount of adhesive asphaltic base held in solution by natural solvents of low boiling point. Both are rich in unsaturated hydrocarbons, and the essential differences between them appear to rest in the fact that the Mexican petroleums have a higher sulphur content than those from Trinidad,[1] and yield appreciable quantities of paraffin scale, which is not found in the Trinidad oils. Both, however, when of proper consistency for the work in question, have yielded satisfactory results when properly applied.

Through processes of experiment and development two general methods of dust prevention and road preservation have resulted:

(1) The treatment of the road surface with substances capable of holding down the dust present and of laying dust brought in from outside sources.

(2) The internal treatment of roads with binders capable of reducing road wear and disintegration and, therefore, dust formation from the road material proper.

The first method, which is generally spoken of as surface treatment, may really be further subdivided with regard to the class of material used and the form of treatment pursued. The purpose is usually accomplished with fluid petroleum products of proper viscosity for hot or cold application, as the case may be. These products are usually classified as temporary and semi-permanent binders, according to the results they will yield. Under the first classification we include those products whose principal function is to hold dust *in situ*, largely by capillarity. They need not necessarily possess any pronounced binding value, and must be applied several times during a season in order to accomplish their purpose satisfactorily. They are generally applied without any extensive preparatory cleaning of the surface, and their only preservative action results from the fact that they hold upon the surface a loose pad of dust and oil. The lighter grades of our native

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[1] Clifford Richardson calls attention to an apparent inaccuracy in this statement. His paper on Characteristics and Differentiation of Native Bitumens and Their Residuals shows that the two types of crude petroleums referred to contain practically the same per cent. of sulphur, 3.28 in Mexican and 3.60 in Trinidad, but that the residuals from Mexican petroleums retain a higher percentage of sulphur than those from Trinidad: *i.e.*, 5.38 as compared to 2.10. The author's statement with regard to sulphur content should have been modified to apply more particularly to residuals, although he has found Mexican crude to contain as high as 4.70 per cent. sulphur.

crude petroleums which are capable of being applied cold will serve the purpose of temporary binders or dust palliatives, and some of the high-boiling distillates have been used with satisfaction. Emulsions of residual petroleums with alkaline soap solutions have also been extensively used in the treatment of park roads, for the reason that they are readily miscible with water and may be cheaply and efficiently applied from an ordinary sprinkling wagon. Emulsions, however, to be successful, should be of such character that they will remain emulsified when mixed with water, and after application will evaporate in such form that they may not be readily washed out by rain.

Semi-permanent binders constitute the class of petroleum products which will yield efficient results on a single application or less per season, and their use involves real surface treatment as now generally understood. They should be applied to a thoroughly cleaned road surface for the purpose of forming a wearing surface or mat with the rock screenings or gravel with which the application of oil is covered. A treatment of this character acts not only as a dust preventive in that it holds to some extent extraneous dust which may be brought on to the surface, but also as a road preservative in that it takes the wear which would otherwise come upon the road material proper. The cost of maintaining a surface mat of this character is dependent upon climatic and traffic conditions, but, as a general proposition, it may be said that it gives best surface under traffic in which automobiles are the predominating class. The Office of Public Roads is at present watching with interest a series of experiments in which 9 miles of newly resurfaced limestone macadam was treated in sections with seven different surfacing materials. Both hot and cold applications were made with three varieties of tar products and four of petroleum products. Traffic censuses are being regularly made and accurate maintenance data kept with a view to determining the relative economy of the several experiments.

The results of observations to date would indicate that a petroleum product to prove of value as a semi-permanent binder in surface treatment should possess decided adhesive qualities or should at least develop such properties in the residue from the standard volatilization test at 163° C. These qualities are, of course, most pronounced in petroleums which we have classified as asphaltic. For cold treatment, those oils, either natural or artificially prepared, which consist of a light solvent carrying a sufficient quantity of viscous adhesive base, have met with much favor of late. Such oils are of a consistency to be readily applied without heating, but owing to the volatility of the solvent they possess the characteristic of "setting up" with fair rapidity.

For hot surface treatment the heavy residuals from asphaltic oils or from those semi-asphaltic petroleums which contain a sufficient amount of unsaturated hydrocarbons to yield products of well-defined binding

quantities prove best. Eastern petroleums or those from other localities which are rich in paraffin hydrocarbons are not adapted to the preparation of semi-permanent binders.

The second method or internal treatment for road preservatives is generally accomplished by one of two methods.

In the penetration method, the best practice is to place upon the subgrade, prepared as for ordinary macadam work, a foundation course of No. 1 crushed stone to the desired depth. This is well rolled, with the addition if necessary of sand or screenings to thoroughly bond the course, care being taken that there is no excess of fine material which will prevent the wearing course from keying into the foundation. The road is then rolled until absolutely firm, more screenings being applied if necessary to take the place of those worked into the foundation. The wearing course of No. 2 crushed stone, clean and free from dust and screenings, is then applied to a finished depth of 2 or 3 in., and this course lightly rolled. The hot bitumen is next poured or sprayed upon the road at the rate of about 1½ gal. per square yard, after which a light coat of clean ½-in. stone chips, free from dust, is applied and the road well rolled. A seal coat of bitumen is then painted upon the surface at the rate of from ½ to ¾ gal. per square yard, after which screenings are applied and rolled in until the road is smooth and firm.

In general, the mixing method is conducted as follows: Upon a foundation course of crushed stone, prepared in the same manner as for the penetration method, a mixture of crushed stone and bitumen is laid to a finished depth of from 2 to 3 in. and rolled, with the addition of screenings. A paint coat of bitumen is then applied and the road finished off in the manner previously described. The mixture of stone and bitumen may be prepared either by manual labor or by machinery, preferably the latter, and the mineral aggregate may be graded in any approved manner.

Both of these forms of wearing surfaces are sometimes laid over a concrete base, and the mixing method is frequently varied by carefully grading the aggregate or adding a given portion of sand to the stone with a view to forming a denser surface.

For construction work of the above character we use what we are accustomed to term permanent binders, which include the heavy semi-solids or asphalts prepared from petroleum. They are preferably obtained from asphaltic petroleums either by direct distillation or by distillation with air agitation. By the latter method, when properly carried out, it is possible to obtain a product of given consistency at a lower distillation temperature than would otherwise be the case. Certain grades of semi-asphaltic petroleums from our middle Western and Gulf fields yield satisfactory binders, which are sometimes reinforced by the addition of gilsonite. The proper consistency of a permanent binder

for any given piece of work will be dependent upon the location of the project, climatic and traffic conditions, and the nature and grading of the aggregate, so that no one standard grade can be recommended for construction work in general. And even the general classification of binders, as above given for use in the treatment of broken stone roads, may vary somewhat where they are to be used in conjunction with certain types of road rock. In recent experimental work in Florida, under the supervision of the Office of Public Roads, an effort was made to develop a method of bituminous construction in which the soft, powdery, and absorbent native coralline rock could be used. What we would customarily designate as a permanent binder would not adhere to this material, but excellent results were obtained by the penetration method in the use of a viscous fluid product that would ordinarily be classified as suitable for surface treatment only.

The author has attempted to cover in a short paper the principal types of petroleum products which are used throughout the United States for the purposes of dust prevention and road preservation, the general methods by which they are applied, and a few of the desiderata which a petroleum product should possess when selected for a given purpose. The finer details of manufacture, selection, and use all offer subjects for much more extended discussion than the present occasion would necessitate or permit.

Discussion

Walter Wilson Crosby,* Baltimore, Md. (communication to the Secretary†).—The comprehensive but concise treatment of the subject by the author is gratifying and the writer wishes to compliment Mr. Page on his presentation of his topic. In the main the writer believes the author correct in his statements, but there are one or two points on which he believes the author is not quite clear and possibly is misinformed. For instance, the author may mean to convey the impression, by the latter part of his first paragraph, that present-day highway engineers agree that water-bound macadam is a thing of the past, or is rapidly growing to be so. If this is what the author means to say, the writer disagrees with him, and believes that so do the majority of the better informed and less radical highway engineers.

With the introduction of the use of bituminous material, such as petroleum products, in highway construction and maintenance, there was a tendency among the less conservative highway engineers to jump to the conclusion that water-bound macadam would quickly be supplanted by bituminous roads of various sorts. Recently a reaction has set in, and the position of the more conservative engineers in the matter has been more clearly recognized. As a matter of fact, water-bound macadam protected with a coating or carpet of bituminous material and grit is

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* Non-member. † Received Mar. 11, 1914.

ust beginning to obtain the recognition due it as a most useful road crust ınder modern traffic conditions in many cases. This fact is fully recogıized in England and in some parts of this country. The writer, at the ·isk of appearing to digress from the subject under consideration, feels mpelled to call attention to this point in this discussion, because of his knowledge that a deduction, such as might be founded on the author's statement in this connection, is constantly being used as an argument against the further construction of water-bound macadam on country ·oads and for the construction of the much more expensive pavements, and he agrees with the statement recently made by Hon. S. Percy Hooker, State Superintendent of Highways, New Hampshire, who has said:

"I believe that more economic waste has been entailed by the use of an improper ype of road than in any other way. This, to my mind, does not mean that too cheap oads have been built. In many instances, I think the error is directly opposite to his. State Departments in the last few years, overwhelmed by the magnitude of the naintenance cost of certain types of roads, have many of them rushed to the other xtreme. They have adopted almost entirely the pavement type of road costing nywhere from $15,000 to $25,000 per mile, and, especially where the money has been rocured under bond issues, they have actually in the way of interest incurred a reater maintenance charge than the actual maintenance charge which they are seekng to avoid."

The author in speaking of the mid-continent oils says that "they are f a naturally greasy consistency and cannot be made to develop any dhesive properties by refining processes." If the author means hereby) condemn any products from these oils for road-making purposes, the ·riter thinks he goes too far. In certain forms of construction, such as in well-rolled and mechanically bonded macadam, where the stones have een so kneaded together under the roller that the voids are reduced to a ninimum, though not filled with fine material, and the particles of stone ·e well keyed together, the desirability for high adhesive qualities to the oid filler (the petroleum product or bituminous material) is low, and in ıch cases very satisfactory results indeed have been had from the use of ·operly prepared products from the mid-continent field. The petroum product in these cases is frequently referred to as the "binder," and, ıder such conditions, any inference from the statements of the author ıat the mid-continent field cannot produce satisfactory "binders" seems) the writer to be too broad.

In referring to the penetration method of constructing bituminous ad crusts, the author says that "the best practice is" to have the wearg course of No. 2 crushed stone "lightly rolled," then to use about $1\frac{1}{2}$ ıl. of hot "bitumen" (*sic*) per square yard, and finally to apply a seal oat of "bitumen" at the rate of from $\frac{1}{2}$ to $\frac{3}{4}$ gal. per square yard, on which ·reenings are spread and rolled. Evidently the author is misinformed ere, for the recognition is now general of the desirability for a *thorough* olling, not a *light* one, of the wearing course or No. 2 stone before the

application of the bituminous material. (The author probably does not mean "bitumen," in his use of the word, to be taken strictly in accordance with the definition for the word adopted by the Committee (*D*-4) of the American Society for Testing Materials, of which the author is Chairman.) Further, the statement that the "best practice" is to finally complete the construction under the penetration method with the use of a seal coat may be seriously questioned, and even when a seal coat is used, it is seldom if ever successfully used in the maximum quantity stated by the author. One-quarter to one-half a gallon per square yard would have been the better statement.

The author's remarks as to the effect of climatic, traffic and other conditions on the choice of a binder are well made, and apply with equal force, in the opinion of the writer, to the selection of the methods of construction, the selection of all the materials, and to the other details of the general subject.

Scientific Installations for the Economical Burning of Liquid Fuel of any Specific Gravity

BY WILLIAM NEWTON BEST,* NEW YORK, N. Y.

(New York Meeting, February, 1914)

Oil burners, oil furnaces, and methods of installation, have been the subject of many articles, but information concerning oil-burning systems, based upon scientific principles, is still in great demand, especially in the manufacturing districts of our country.

Fuel oil, as it is termed (this being the residuum from oil refineries), has for many years been of great service to our manufacturers, and has justified its popularity not only by producing a superior manufactured product, but by turning out approximately 50 per cent. more product than can be made with coal fuel under like conditions. To install a system requiring only an oil-storage tank, a small pump, and an oil-supply main with numerous laterals leading to the various burners, furnaces, boilers, etc., is a comparatively simple matter; and, because fuel oil is very volatile, it is not necessary to heat it, even during the winter months in a very cold climate. Furthermore, only a small amount of power is required to atomize fuel oil, this often being done by a positive pressure blower, or by a mechanical burner. An analysis of fuel oil, together with that of various other liquid fuels, is given in Table I.

TABLE I.—*Analyses of Liquid Fuels*

	Fuel oil	California asphaltum base crude oil	Mexican (Tampico Field) crude oil
Carbon, per cent	84.35	81.52	83.83
Hydrogen, per cent	11.33	11.01	12.19
Oxygen, per cent	2.82	....	0.43
Nitrogen, per cent	0.60	6.92	1.72
Sulphur, per cent	0.90	0.55	2.83
Gravity, degrees Baumé	26 to 28	12 to 36	12 to 23.8
Weight, pounds per gallon	7.3	7.6	7.82
Calorific value, B.t.u. per lb	18,350 to 19,348	18,462 to 18,980	18,493
Vaporizing point, degrees F	130	230	175

* Vice-Chairman, Committee on Petroleum and Gas.

In the middle and eastern sections of the United States, four systems for burning fuel oil have been successfully employed: namely, gravity feed; column gravity feed; the pneumatic system; and oil-pump feed.

Gravity Feed.—In the gravity-feed system, the oil is supplied to the burner from a supply tank located approximately 8 ft. higher than the burners. This is the cheapest and most simple system to install and operate, but is not approved by the National Board of Fire Underwriters.

Column Gravity Feed.—By column gravity feed, the oil is pumped from the storage tank through the supply pipes to the burners. The excess oil is then forced into a column, consisting of a pipe 2 in. in diameter and approximately 20 ft. in height, provided at the top with a vent and an overflow pipe, which carries the excess oil which overflows back to the oil-storage tank. It is obvious that by this method, the pressure maintained at any burner depends upon the difference in level between the burner and the top of the oil column. When this difference in level is 16 ft., the corresponding pressure would be approximately $7\frac{1}{2}$ lb.

The Pneumatic System.—In the pneumatic system, the compressed-air line of the factory is connected to the top of the oil-storage tank, thus putting the oil under a pressure, which may be regulated and controlled by means of an adjustable set-screw on the pressure-reducing valve on the compressed-air line. The pipe which supplies oil to the shop is coupled at or near the bottom of the oil-storage tank.

Oil-Pump Feed.—The pumping system is now most commonly used. Here a pump is employed to force the fuel from the storage tank and deliver it through a main supply pipe and laterals leading from it to the different burners. A pressure-relief valve, located at or near the pump, maintains the required oil pressure, as well as allowing the excess oil to return through an overflow pipe to the storage tank. In this system, the oil-storage tank is provided with a filling pipe, usually 3 in. in diameter; a man-hole; and a vent for the escape of gas. The regulations of the National Board of Fire Underwriters in the central and eastern parts of this country, require the tank, or tanks, to be located at least 30 ft. from any building, and to be covered with 2 ft. of earth. The type of oil pump is sometimes reciprocating, operated either by compressed air or by steam, and sometimes rotary or triplex, driven either by motor or by belt.

The Use of Oils Heavier than Fuel Oils.—The advent and popularity of automobiles and oil engines has created such a demand for by-products of fuel oil that it has now become too valuable to be used as fuel, notwithstanding its excellent quality. The manufacturing world must, therefore, install in future some system by which heavier oils can be used, and especially petroleums from the Mexican and Southern California fields, which are particularly available as fuel, because they contain so small a proportion of volatile oil, gasoline, kerosene, etc. Analyses

of Californian and Mexican crude oils are given in Table I. The completion of the Panama Canal will, no doubt, result in vast quantities of this fuel being delivered to the southern and Atlantic ports of the United States.

Efforts have been made in the eastern parts of the United States during the past year and a half, to burn the heavy petroleum from the Mexican fields, which has an average gravity of 14° Baumé. Through ignorance, when attempting to use this oil, no means were provided for heating the fuel in the storage tank; the oil pump which had been used for ordinary fuel was not changed to adapt it for a heavier fuel; the oil pipe lines were not laid so that the fuel would be constantly in circulation; and the pressure valve was not located appropriately for the heavier oil. The result was that the fuel system had to be shut down until the oil had been removed from the tanks by buckets.

I have often been amused by the efforts of persons who were accustomed to burn fuel oil, but who were not familiar with the use of heavy crude oils. For, notwithstanding that the heavy crude oil, when appropriately handled, is a better fuel than ordinary so-called fuel oil, because it has a higher calorific value per gallon, nevertheless, these efforts have often resulted in crude oil being condemned.

Oil-Burning Systems.—The system shown in Fig. 1, by the use of which any petroleum from 12° to 46° Baumé can be scientifically used as a fuel, comprises: an oil-storage tank provided with a 5-in. filling pipe, a $\frac{3}{4}$-in. steam coil, a man-hole, a vent pipe, an overflow pipe, a suction-pipe flange, etc., as required by the National Board of Fire Underwriters; an oil pump of adequate proportions operated by steam or compressed air, or, if it be a triplex pump, driven by a belt or motor; and an oil-supply pipe so located that it follows the line of furnaces, boilers, kilns or other equipment, without the use of laterals, and with riser pipes from oil-supply pipe to burners, each of which must not exceed 3 ft. in. length. The system must also include an appropriately located pressure-relief valve, and, adjacent to it, a by-pass valve to drain the oil-supply pipes when the system is not in service. An overflow pipe is connected with the relief valve and also with the by-pass valve, so that the excess oil will be led back to the storage tank. This system insures a constant, perfect circulation of the oil to each burner, and eliminates all dead ends on the supply lines.

Coating the oil-pipe threads with a paste consisting of litharge and glycerine, before assembling, will prevent leakage. The unions should be ground joint. Gum or rubber should never be used, and lead gaskets should be used in flanges. I deem it always advisable to use malleable-iron beaded fittings on all oil-pipe lines.

Heating the Oil.—The object of heating the crude oil is to reduce its viscosity, and it should be heated in the storage tank to a temperature

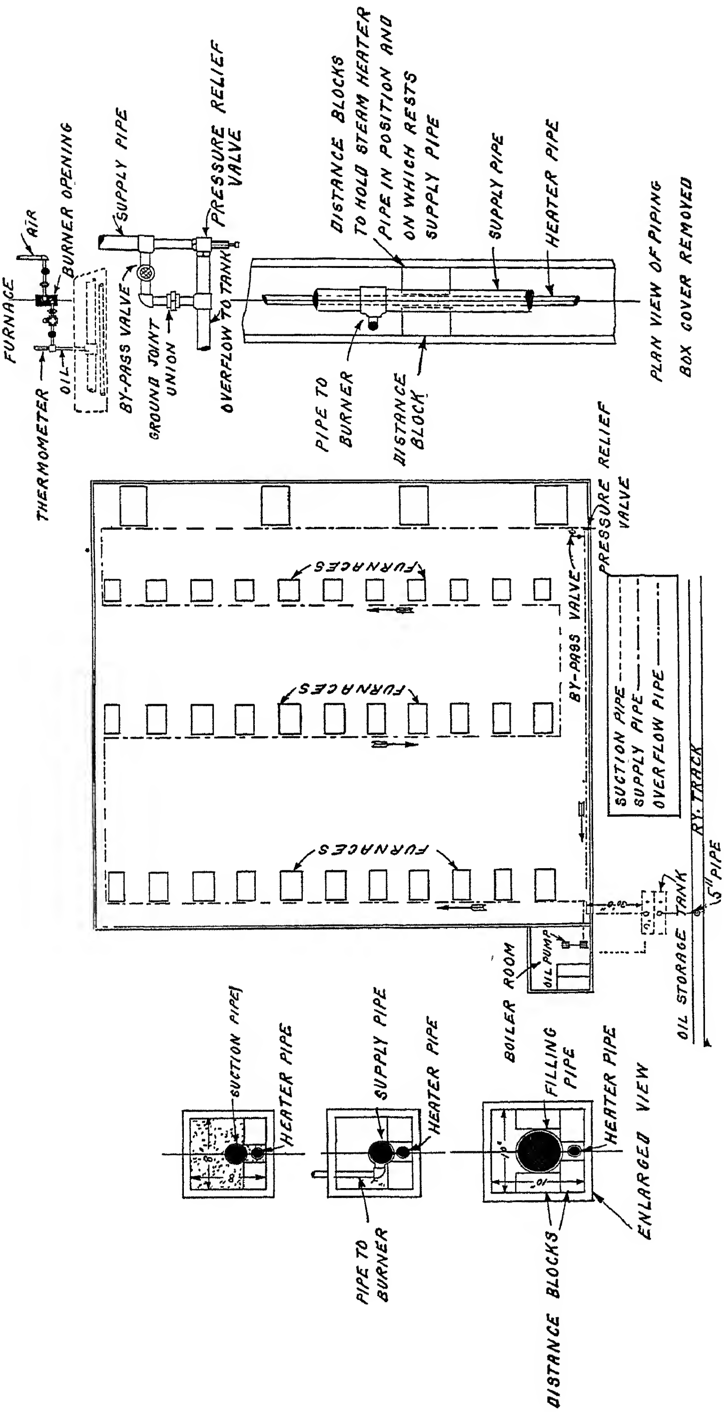

Fig. 1.—Oil-Burning System for Petroleum Between 12° and 46° Baumé.

that will allow it to be pumped easily. The oil is also heated in the supply and overflow pipes by running a steam pipe alongside of them, and inclosing both in an 8-in. square box which, when the pipes have been tested, is filled with dry sand. By regulating the amount of steam passing through the heater pipe, the oil is supplied to the burners at a temperature just below its vaporizing point. When the pipes are inclosed in the manner described only a small quantity of steam is needed, and, by laying the steam pipe below the oil pipe in the box, it is accessible at all times. Some persons prefer to heat the oil by passing a 3/8-in. steam pipe through the oil-supply pipe. The first cost of this is cheaper, but, if the steam pipe should leak, it is difficult to make the necessary repairs.

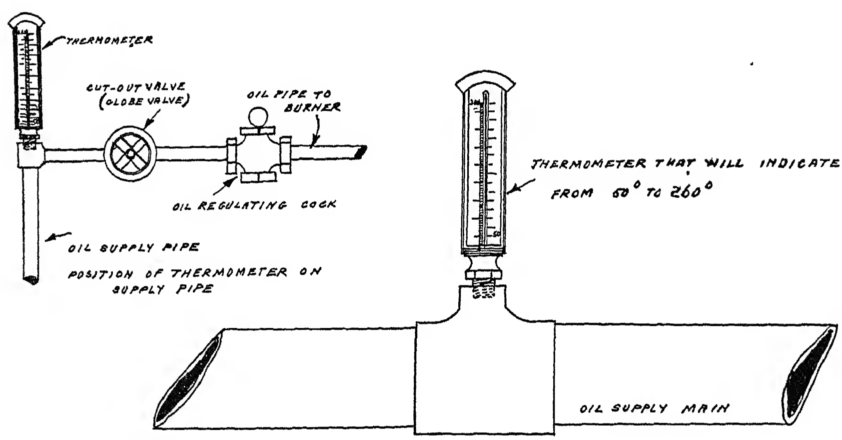

Fig. 2.—Position of Thermometers on Oil-Supply Main.

Accurate Temperature Required.—The economic advantage of accurately heating the oil to the desired temperature is shown by some tests in which a saving of 20 per cent. of Mexican crude oil required was made by heating it to 160° F. (which is 10° below its vaporizing point) instead of 120° F. The control of temperature is so important that thermometers should be used in direct contact with the fuel as it passes to the burner (see Fig. 2). Two or three such thermometers, well located, will save much oil and increase the output of the furnaces. The overheating of the oil is an example of carelessness which should be severely condemned, and which may readily be detected by the puffing of the burner, due to escaping vapor.

Liability to Fire through the Use of Oil.—There is less liability of fire from liquid fuel, employed by means of a modern fuel-supply system, than there is from the use of coal or coke, yet there are many different rules prevailing in different parts of the country for the location of oil-storage tanks. In the eastern and middle sections of our country, the

laws of the National Board of Fire Underwriters require all storage tanks to be placed 30 ft. from any building and covered by 2 ft. of earth, while in San Francisco they are placed in the space formerly used for coal, immediately under the sidewalk, and are filled by oil-tank wagons or oil-tank cars from the street.[1] I have at hand evidence which proves that, of the hundreds of oil-storage tanks located in the city of San Francisco at the time of the late earthquake and disastrous fire, not one exploded or increased the conflagration or was the direct cause of financial loss. It is impossible for many manufacturers to place oil-storage tanks 30 ft. from any building, because their buildings cover their entire ground, and the Fire Underwriters' law quoted forbids them to be placed under the

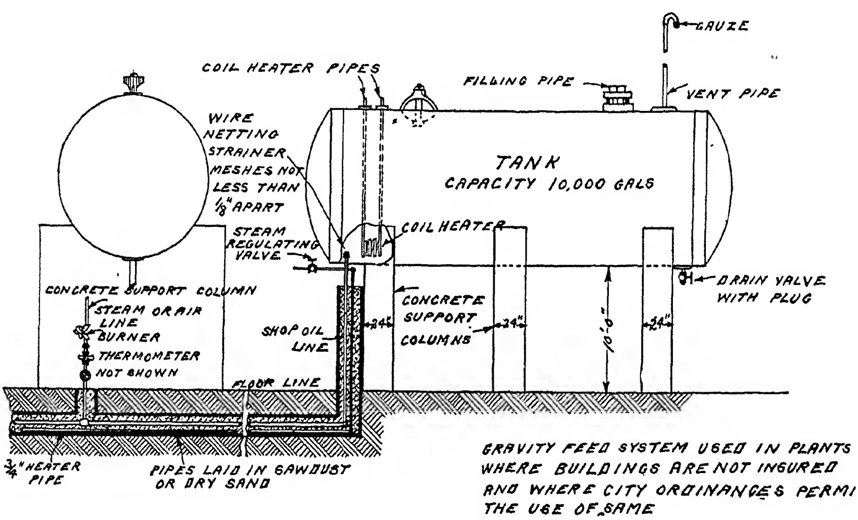

Fig. 3.—Gravity-Feed Oil-Burning System.

sidewalks. This places some manufacturers at an unfair disadvantage in competition with others, because it prohibits them from the use of crude fuel for such purposes as the heat treatment of metals, drop forging, welding, etc.

All manufacturers are to-day looking for quantity as well as quality of output, and, as oil can be safely stored under the street sidewalk in one section of the country, then, why can it not in another section? In other words, why should we not have uniform laws? If crude oil were as volatile as gasoline, there might be some grounds for fear, but it is not. As ta. as the danger from dripping oil is concerned, it may be obviated

[1] Resolution of Executive Committee adopted Aug. 20, 1901, by Board of Fire Underwriters of the Pacific. Circular No. 185.

by sprinkling over the floor of the pump house, and around the storage tank, a mixture of 8 lb. of sodium carbide with 1 bushel of sawdust.

Tar as a Fuel.—The present rapid increase in the use of by-product coke ovens makes available an excellent fuel in the tar which is obtained as a by-product, to the extent of about 10 gal. per ton of coal coked. Many steel works have found it to their advantage to burn this tar, which is usually conveyed to the burners by gravity, the storage tank, as shown in Fig. 3, being placed 3 or 4 ft. above the burners, being provided with a heater coil and with heater pipes running alongside the supply pipes, substantially as described above. Steel plants are seldom insured, and any plant which does not carry insurance can burn heavy oil successfully in the same manner.

"Water-gas tar" is a residuum from gas works using the water-gas system, and is an excellent fuel, which has a calorific value of 16,970

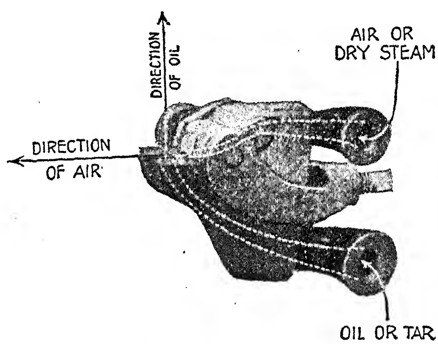

FIG. 4.—FUEL-OIL BURNER.

B.t.u. per pound, equivalent to 161,200 B.t.u. per gallon, there being $9\frac{1}{2}$ lb. of this tar per gallon. It is ordinarily supplied as fuel under the boilers of the plant by the gravity-feed system just described.

Burners.—Burners should be constructed so as to atomize liquid fuel of any specific gravity purchasable in the open market without changing any of the parts and without carbonization. One form of burner is shown in Fig. 4. Burners should be simple to operate, and as few as possible should be used in each equipment. The flames should fill the fire box, or charging space, of the furnaces, completely, in order that the heat may be evenly distributed. If mechanical burners are used, the oil pressure should be sufficient to insure complete atomization, and the construction of the burner should be such as to provide either a round or a flat flame, as required. If atomizing burners are used, the pressure of oil and air or steam must be constant, because any fluctuation in the pressure of either the oil or the medium used for atomizing will give a variation in the kind of flame and in the temperature. For example, we may have

alternatively a flame that is oxidizing, reducing, or smoky, whereas the combustion system should give complete control of the kind of flame whenever necessary. A smoky flame should always be avoided, because it causes loss of fuel and decrease in temperature. Technically speaking, carbon dioxide indicates perfect combustion, while carbon monoxide shows imperfect combustion.

Kinds of Service for which Liquid Fuel is Suitable.—The burning of liquid fuel is a science, and only by burning it scientifically can successful results be obtained. To condemn oil fuel is simply an exhibition of ignorance, for it has been thoroughly tested throughout the eastern and middle States, and the heavy California oil has been successfully burned in every form of service on the Pacific coast for the past 25 years. Petroleum of low specific gravity is the fuel of the twentieth century, and the demand for it will increase every year from every manufacturing nation which endeavors to keep pace with modern progress. No fuel has, however, been so wastefully used as petroleum. For example, many open-

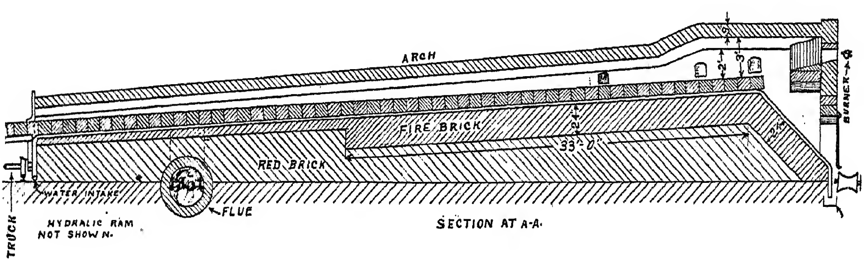

FIG. 5.—CONTINUOUS HEATING FURNACE FOR BILLETS.

hearth furnaces require 61 gal. of oil to produce a ton of steel; whereas, 32 gal. should be sufficient, and I could mention 20 other instances showing equally great variations. A continuous billet-heating furnace, 66 by 10 ft., is shown in Fig. 5.

Petroleum should be used only in those classes of work in which it is more economical than coal, coke, or gas. I regret to say that in many instances it has been employed where it could not possibly compete in price with other fuels produced in the immediate vicinity. Comparisons may be readily made by the following figures: Assuming that the petroleum has the calorific value given in Table I, and assuming that good bituminous coals have calorific values of 14,000 B.t.u. per pound, then, in good drop-forge practice, 60 gal. of oil would be equivalent to 1 long ton of coal; in boiler practice, under like conditions, 147 gal. of oil would be equivalent in evaporating power to 1 long ton of coal; in welding locomotive flues, 58 gal. of oil are equal to a ton of coal, and in locomotive service on an average division, one can ordinarily estimate that 180 gal. of oil are equivalent to a ton of coal. In locomotive service,

the use of oil eliminates the smoke nuisance and the loss caused by the burning of ties, grain fields, forests, or buildings. In large forging plants 82 gal. of oil will do the work of a ton of coal. The use of oil has, of course, the advantage in the matter of there being no ashes to handle, and, in a large plant, one man can fire and water-tend a battery of 12 oil-fired boilers with perfect ease.

During the past five years, oil has been much in demand to increase the efficiency of boilers by supplementing the coal fire during the peak of the load, and has also proven so valuable for emergency boilers in water-power plants, etc., that the actual cost is not considered in this service.

Three barrels of oil (42 gal. per barrel) are equivalent to 4,615 lb. of hickory; 4,200 lb. of white oak; 4,400 lb. of yellow pine. Six gallons of Texas crude oil are equivalent to 1,000 cu. ft. of natural gas.

The calorific value of petroleum produced in all sections of the world is about the same, while the calorific value of coal varies greatly. For example, the calorific value of Pocahontas coal is 15,391 B.t.u per pound, while that of Illinois coal is only 10,000 B.t.u. per pound.

I give these data simply to show that it requires actual operating tests in different classes of service to obtain a definite comparison between the relative value of oil, coal, wood, and gas, as fuel. To attempt to make such a comparison by calculating with the calorific values of the various fuels is only misleading, because heat is required to liberate the gases of coal, and in welding, for example, you must first coke your fire when using bituminous coal, and therefore there is a two-fold waste of fuel; namely, the heat required to liberate the gases and the waste of heat while coking the fire, because it is impossible to weld with a green fire. In flue-welding locomotive flues, commonly termed in railway shops "safe-ending," one can attain and maintain a welding temperature by using modern oil furnaces, and 60 flues can be welded per hour; using coal instead, it is good practice when 14 to 16 flues are welded per hour with the same number of men. Thus the use of coal in this service involves a waste of both time and fuel.

In California, where petroleum is cheap and coke is costly, oil-fired air furnaces should be used, instead of coke-fired cupolas, for making gray iron castings, because oil produces a better quality of metal with a higher tensile strength and the furnace up-keep is less. Fig. 6 is a sectional view of a 12-ton air furnace. California petroleum is low in sulphur, while Mexican oil is high in sulphur, but all consequent difficulty can be obviated if a combustion chamber is used on the furnace and the proper amount of air is admitted under the flame at the correct time and place. If some inventor, having the audacity of genius, would invent an oil-fired cupola of modern construction, it would be a great blessing to those in the foundry practice who are situated where oil can compete in cost with coke in present cupola practice, and, as such a process would

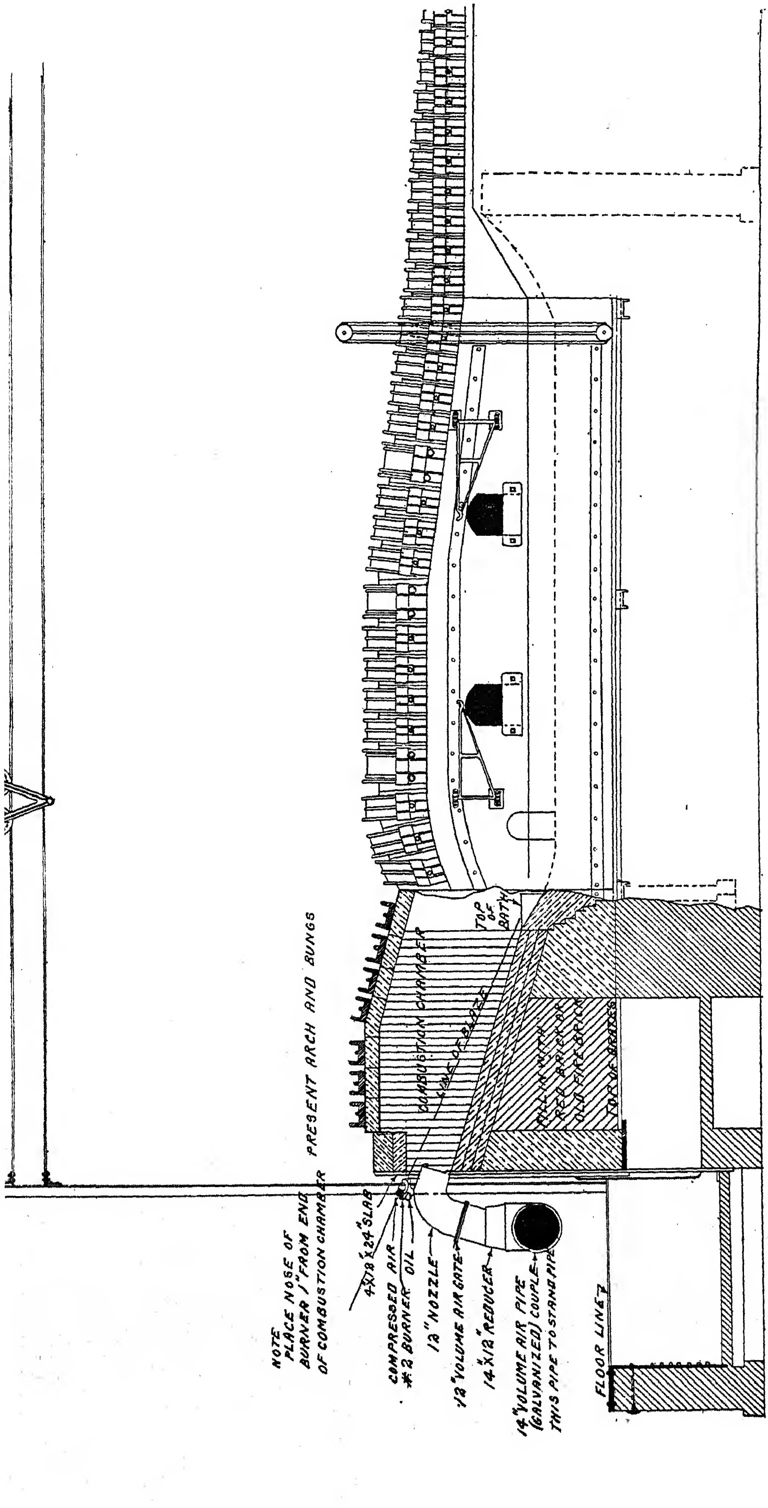

FIG. 6.—TWELVE-TON AIR FURNACE OPERATED WITH ONE BURNER.

occupy but one-fourth of the shop space of a corresponding air furnace, it would be in great demand.

The value of certain steels depends upon their heat treatment, and. because of the perfect distribution of the heat and the absolute control over the temperature, oil is an incomparable fuel for this purpose.

In the types of service mentioned below, the use of oil has been thoroughly tested, and it has been found to be an ideal fuel, but, of course, the economic effect will depend upon the relative price of oil and coal in the locality where the industry is carried on: For annealing, for asphaltum mixers, Babbitt heating, bolt making, brass melting, brazing, bread ovens, etc., brick and art-tile kilns, case hardening, cast-iron melting, rotary cement kilns, channel-iron heating, chocolate-bean roasting, continuous heating, copper-plate heating, copper refining, core drying, crematories, crucible brass melting, crucible steel melting, drop forging, enameling, flue welding, glass lehrs, glass melting, incinerators, indirect-fired furnaces, japanning ovens, ladle heating, locomotive steam raising, locomotive-tire heating, malleable-iron and gray-iron air furnaces, mold drying, ore smelting, plate heating, pipe bending, pipe-flange welding, portable torches, rivet making, rolling-mill work, rotary kilns, shaft and billet heating, sand drying, sheet-steel heating, steel melting, steel mixers, tar stills, tempering, welding scrap iron, wire annealing, wire making, as well as stationary, marine, and locomotive boilers of all types and capacities.

In conclusion, I refer to an exhaustive report compiled in 1904 by the Liquid Fuel Board of the United States Navy. The test was under the direction of the late Rear Admiral George W. Melville, but the work was done by the President of the Liquid Fuel Board, one of our honored members, Rear Admiral John R. Edwards. This report stands to-day as the highest authority in marine boiler practice. The fuels used were procured from various sections of the United States, and these tests brought liquid fuel to the attention of the world, with the result that all the leading nations are installing it on their battle ships, and some authorities believe that the liquid-fuel question is one which may determine the relative naval strength of the nations. It should, therefore, be our aim as loyal Americans to obtain as wide a knowledge of this fuel as possible, and we believe that the American Institute of Mining Engineers was not only serving the best interests of the manufacturing world, but those of our nation, when it established the Committee on Petroleum and Gas, to promote research on this important fuel, the supply of which we believe to be fully equal to the demand, as has been the case with coal, natural gas, and other fuels.

Discussion

E. H. Hamilton, West Norfolk, Va.—I think I was about the first to use oil in large reverberators, for copper smelting, and our records show that we got better results generally per B.t.u. from the oil than from any other fuel. It did away with all fire-box losses from below the grates, and the boilers could be regulated to suit any purpose. Sometimes we ran the furnace for steam, and sometimes for oil. Incidentally all the time it was for smelting. We found the efficiency of the smelting depended upon the highest point of temperature, and we had to feed the charge at the hottest point of the furnace, which was in a different position from a furnace fired by any other kind of fuel. We moved the charge to suit the point of high temperature.

H. O. Hofman, Boston, Mass.—In regard to the use of fuel oil, I think it would be of interest if Mr. Best made some remarks upon the use of steam and air as atomizers. As I recall it, in perusing the paper, this subject has not been touched upon. In smelting sulphide copper ores in a reverberatory furnace, our metallurgists have tried steam, low-pressure air, and high-pressure air for atomizing; all have given up steam and low-pressure air and use air at a pressure of 12 to 14 lb.

In reference to the remarks made by the last speaker about the high efficiency of oil, I may recall that Mr. Mathewson, in his paper on the use of bituminous coal in firing reverberatory matting furnaces, found that he did not derive any advantage in increasing the length of his furnaces beyond 100 ft. It has been found that you can do this in firing with oil; in fact, Mr. Sörensen, at the works of the Nevada Consolidated Co., has in operation a furnace 130 ft. in length; he believes that the greatest permissible length is 140 ft. This may be due to two causes: One is the high calorific power of the oil, and the second, that oil is fed continuously; we have continuous feeding and firing. With the modern method of supplying coal to the copper reverberatory matting furnace, in which coal is fed every 10 or 15 min. from the top of the furnace, there is an interrupted feed. With every addition of coal the fire must cool down. For this reason the temperature in the oil-fired furnace is higher than in the coal-fired, and the heat extends for a longer distance, which makes the longer furnace possible. The smelting power is also greater. Wherever it is economically possible, oil has replaced bituminous coal for firing. A good example of this rivalry is shown at the Garfield smeltery, where bituminous coal and oil were used at the same time in two furnaces and where oil has replaced bituminous coal.

E. W. Parker, Washington, D. C.—Professor Hofman might give us some information regarding the use of mechanical stokers in metallurgical furnaces.

Professor Hofman.—Some experiments have been made in using a

mechanical stoker in firing a reverberatory furnace treating native copper ore at Lake Superior, but no report of the results has been made public as yet.

E. H. Hamilton.—When I was at the Pueblo smelter we fired our mechanical roasters with oil, and the Standard Oil Co. kept putting up the price, so we put in mechanical stokers, and they worked very efficiently. The stoker was called the American stoker, and with certain coals it worked very well.

Karl Nibecker, Youngstown, Ohio.—I notice that Mr. Best gives some values for the amount of oil used in various heating furnaces which would be equivalent to 1 ton of coal burned in the same type of furnace. I would like to know whether these values are compared with coal burned in the furnaces, or in the form of gas. As powdered coal appears to be one of the most economical methods of burning the fuel for heating furnaces, can Mr. Best give us any comparisons of the amount of coal required in a heating furnace, as compared to a ton of powdered coal? As there at present seems to be some doubt about the value of powdered coal in a boiler, I do not feel that that phase of the comparison would be of such vital interest."

If Mr. Best has any comparative figures along these lines I feel that they would be of considerable value to operators of heating furnaces.

Leonard Waldo, New York, N.Y.—With fuel oil things can be done and quickly done that are harder to do in any other way. The heat gradient can be pushed, instead of lagging along for hours. It can almost be put on a straight line. That comes from the extremely efficient way in which the oil can be burned.

In regard to the calorific value, the B.t.u. per pound, of 18,493, given for Mexican oil, I would say that many samples increase this to 19,200, from which follows this corollary: That gallon per gallon it is higher than any other oils, but pound for pound is somewhat less, as Mexican crude oils have a high specific gravity. In regard to the details through this paper of the burning apparatus for burning oil, no one who has not experienced the burning in the field can know the value of these suggestions. It is necessary that you should lead the horse to water, before he takes his drink, and in regard to these fuel oils, at 2,000 seconds on the viscometer, ordinary temperature of outside air, the oils may refuse to move, even though your pumps may be forced to the point where the gaskets break out and your pipes split. Therefore, we owe great thanks to the gentleman who has spoken, for the careful way in which he has set out the practical details. I do not know that they occur in any other literature.

In regard to flash tests and the fire risks of oil, the literature is based on the old flash and combustion points, which have crept in from the

petroleum series, and when a Mexican crude oil comes with a flash point of 125° we feel that to use that on our work would insure our early departure from this world. But these flash points are determined, and the amount of actual vapor with 125° flash point, in perhaps 1 or 2 per cent. of the great bulk of the oil. Only 1 or 2 per cent. of it has that flash point. It will make its first flash, and the flash point is recorded as being 125°, whereas that is the flash point of but a very small fraction of the oil, and the total amount of vapor lying on the top of that oil is so slight that the oil will flash like lycopodium in a theater.

I was standing by some laborers who had a fear of the oil, and one said, "I am going to try the stuff. Come with me." He filled a galvanized bucket with the oil, got a light at the furnace, and plunged it in the bucket. Nothing happened, only the light was put out. The same conditions govern the experiments at sea. In the case of the "Volturno," the waves were covered, and if it had a dangerous point it would have been shown there. We must revise our whole idea of flash points when they relate to a very small fraction of a mass of the oil, the total sum of which is insufficient to raise the temperature of the whole body above a fraction of a degree. If you have a large tank of oil, and you are carrying a 10-ton mass to be cooled or quenched in oil, sometimes the heat of the large mass will raise the temperature of the mass of oil to a dangerous point. But if you have a trundle bed and a roof shoved out and covering the tank, the whole conflagration is at once extinguished, and you have a safe use of these oils. Where you have a quick extinguisher for the oil, it is safe.

Now, in regard to the use of air or steam for atomization: In the furnaces, it does not seem to make very much difference which is used, as far as the atomization of the oil is concerned, but there are certain indirect advantages in using air. I cannot refer to them here, as they involve the chemistry of combustion; but steam is used at some important furnaces for atomization, and it is very effective, but in those cases the air supply is carefully regulated from other sources.

Our literature is lacking most in viscosities at varying temperatures. Fortunately for us, but unfortunately for our predictions, the viscosity curve for these heavy oils must be considered. It increases rapidly after it reaches 40° or 45° F., and then it goes up very rapidly. I would like to suggest to the Bureau of Mines that we desire additional information in that field.

W. N. Best.—In relation to the atomization of the oil, either steam or air may be used to atomize the oil. When using heavy oil in large furnaces it is necessary to use air or steam at 80 lb. pressure in order to thoroughly atomize the required quantity of oil and distribute the heat, but small furnaces require only about 20 lb. pressure. In either case about forty-nine-fiftieths of the air requisite for combustion passes in through the air nozzle at 3 oz. pressure, and therefore you have the strict-

est possible economy by using a small quantity of air or steam to atomize the oil and distribute the heat and admitting the additional air required through a nozzle at low pressure. Relative to the economy of using steam and air at 80 lb. as atomizer, air will show a saving over steam of over 12 per cent. in fuel, but it requires 8 per cent. of the oil saved to compress the air; therefore you have a net saving by the use of air over steam of 4 per cent. in fuel.

Now, answering the question relative to pulverized coal: The figures given relate to bituminous coal, and it is referred to in the paper as bituminous coal. I have had no experience in running tests against pulverized coal.

The data given in this paper are the result of 26 years' hard work, and thousands of tests, and there is not a week but men come into my office and say, "Mr. Best, we want our boilers equipped; we have gotten on so successfully with our furnaces that we want the boilers equipped with oil also." But I have refused to do it, as I know the additional quantity of oil required to represent a ton of coal in the boilers, whereas, in furnaces a 60 per cent. economy over coal is often effected.

E. Gybbon Spilsbury, New York, N. Y.—Dr. Waldo seems to place emphasis on the fact that there is little or no difference in the use of steam instead of air for atomizing the oil used either for melting or heating iron or steel. I would like to strike a note of warning against the use of steam instead of air as a means of introducing liquid fuel into iron-melting or heating furnaces. An experience I had some years ago demonstrated the danger of the use of water vapor for this purpose. About 1887–88, the Bethlehem Iron Co. introduced the Archer water-gas producers for their billet-heating furnaces, and as it turned out later the results were very disastrous. At about the same time I adopted the same method for heating furnaces at the works of the Trenton Iron Co. The billets I had been purchasing from the Bethlehem Iron Co. had always been extremely soft and ductile; in fact, the company had made a great reputation for itself on this particular brand of open-hearth billets. All at once the character of the steel changed entirely and it became so brittle as to make it absolutely worthless. Investigations carried on both by our company and the Bethlehem Iron Co. failed to show any cause for this remarkable change of character; the records of the heat—taken from the open hearth where the billets were made—showed no change from former practice, and the analyses of the material were exactly the same as they had been for years previous. Nothing that we could do in the way of annealing or slow cooling seemed to have any effect on the material. Finally, Porter Shimer, after making a number of very exhaustive analyses, called my attention to the fact of a larger evolution of hydrogen gas in dissolving this material than he had noticed in other steels. In tracing the matter back it was found that the beginning of the trouble was coinci-

dent with the introduction of the Archer producers, and it was entirely remedied when ordinary producer gas was used in the heating furnaces instead of that produced by the Archer method. It was evident that the brittleness of the steel was due to the absorption of hydrogen by the hot steel the moment it came in contact with this hydrogen in its nascent state. While we found that annealing in the ordinary pot method failed to reduce or drive off the hydrogen, it was demonstrated later that a gradual occlusion of the hydrogen took place, so that after some few months' exposure to the air billets and rods would recover their ductility almost to the same extent as similar material which had not been exposed to the hydrogen effect.

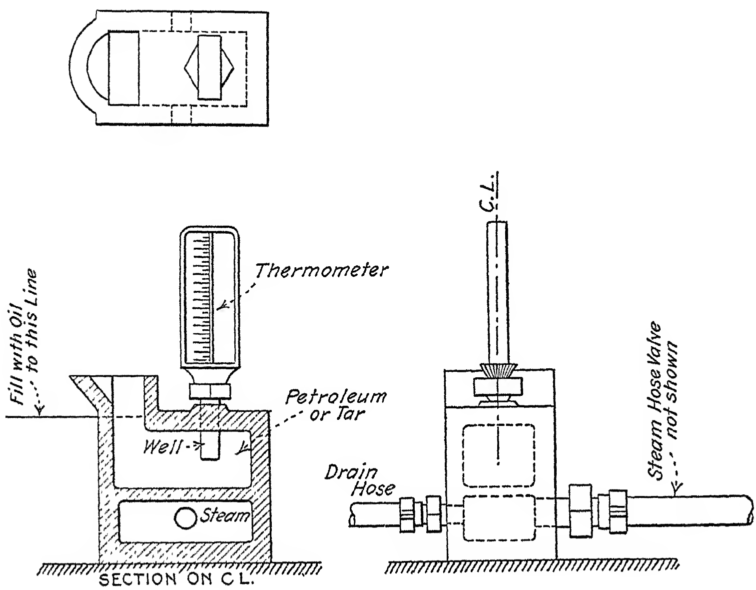

Fig. 7.—Retort for Determining Vaporization Point of Petroleum.

David T. Day, Washington, D. C.—I would like to ask Mr. Best what he means by the vaporization point; and I would like to ask Mr. Waldo what oil was on the tank steamer that blew up in the river, where it came from, and what its flash point was.

W. N. Best.—The point at which the oil when heated casts off visible vapors. For example, the Mexican oil vaporizes at 175° F. or thereabouts and you ordinarily carry a temperature of about 160° F. on the oil line to burners. If you carry it at 180° F. there will be noticeable puffs of flame from the burner, simply because the vapor and the oil pass intermittently out of the burner.

Mr. Day.—I only want to know how you distinguish that from the ordinary flash point.

W. N. Best.—I do not deal with flash points in my paper. There are two different ways of distinguishing the vaporizing point: one is by the color of the flame in the furnace (one moment there being perfect combustion and the next imperfect combustion), and the other is by the unsteady noise while the burner is in operation.

Mr. Day.—Then how would you determine the vaporization point, the point at which it vaporizes?

W. N. Best.—That is determined by heating it with steam in a small receptacle, as shown in Fig. 7. The temperature of steam at 100 lb. is 338° F. Soon perceptible vapors will arise from the oil in the receptacle, and as soon as that occurs you have the temperature at which the oil vaporizes.

C. W. Washburne, Washington, D. C.—Isn't it true that all hydrocarbons have a vapor pressure, and that there is some vapor escaping at all pressures; and there can be no scientific point determined? It must be some particular point at which a great deal of vapor is given off, and I should think that was variable.

W. N. Best.—It is true that some imperceptible vapor is constantly passing from the oil, but that to which I refer is the vapor formed in large quantities when the oil is heated in order to reduce its viscosity, as described in my article. When the oil is heated beyond a certain point, vapor forms and causes an intermittent flow of oil through the burner. The oil should be heated to just below the temperature at which vapor in large quantities is generated and that temperature can be maintained within 5° or 6° by the operator. I now refer to heavy oil, for light fuel oil does not require heating.

E. H. Hamilton.—We used to burn 300 barrels a day, and when we sampled it with the same accuracy that we sampled gold and silver and copper ores, I found the B.t.u.'s were lower than the published statements. This was probably due to water in suspension, but it is a fact that when we tested those samples for B.t.u., we did not get as high results as we were supposed to get.

Leonard Waldo.—Vapor is generated from all oils. I think we will see a complete change in our literature on the subject of flash tests of oil.

Now, Mr. Spilsbury has asked a question which I thought I had concealed under the remark that we would not touch on the chemistry of the burner. But he raises the question. Atomizing oil has a two-fold function; one is to atomize the oil, get it into a smaller molecule and deliver it in small quantities at distances of 40 or 60 or 100 ft., and that takes pressure. In many plants they prefer to substitute steam for the purpose, for while it is easy to get steam over 100 to 120 lb., it is hard to get air, and therefore while the contention of the members is quite true, there are

steel makers to-day who adhere to the use of steam against this advice, and with as good result as in its use on the locomotive. I personally use air, and will go to any pains to get the air for that purpose.

In regard to that explosion: Explosions will take place in an oil tank when it is relatively empty. It is only necessary to have a small quantity of oil in the tank, and a careless workman who insists on lighting his pipe in the bottom of the tank, and all the data of your experiment can be measured afterward, and the original proportions for it are there.

Now, in these explosions at sea, I tried to get the data. In regard to the one cited, I have no data as to that. But in cases at sea where bad explosions have taken place from the flare-back of a flame under the boiler, they would have been avoided if the oil had been used more economically, and burned in the cylinder of the engine. Oil properly used and stored is statistically a safer fuel than coal.

INDEX.

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